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(The usual Annual Meeting article does not appear in this issue because material for it had not arrived from Cornell by press-time. The series will be continued soon, and the Annual Meeting is at Ithaca, June 17–21.)

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DO YOU KNOW . . . .

► . . . . That the Annual Meeting will be at Cornell University on June 17–21? Among Society activities on which it is expected reports of progress will be presented are Development of Engineering Faculties, Technical Institute Survey, Evaluation Follow-Up—the six engineering sciences for all engineers and analysis and design, and Graduate Study.

► . . . . That preliminary information from the Relations with Industry Division indicates they will have a "far-seeing" program at the Cornell Annual Meeting? The papers are to be developed on the theme "the engineering graduate of *1965*." A forward-looking dean will explain the philosophy of the new engineering curricula which should be in effect by then, a department head will forecast some implications of the "new look" for his instructional level, a technical institute educator will explain what his graduates will have to offer, and an industrialist will discuss the new and more challenging high-level professional jobs in which engineers and scientists will by 1965 be increasingly involved. These presentations will set the stage for a panel discussion of problems expected for industry in 1965, especially those relating to the employment of engineers.

► . . . . That the committee in charge of the Society's newest project has been officially named the "Committee for Development of Engineering Faculties"—CDEF if you like alphabetical notations. Dean Harold Hazen of MIT is chairman, and the executive committee consists of J. C. Boyce of IIT, G. B. Carson of Ohio State, M. D. Hooven of the Public Service Electric and Gas Co., Newark, N. J., and W. C. White of Northeastern; Dr. W. H. Miernyk of Northeastern is the Executive Director. The committee is charged with the important task of examining the entire problem of recruiting, developing, and utilizing engineering faculties. The study is to result in recommendations for solving the major problem, and has top priority in all Society efforts. The project has the support of EJC and ECPD and the formal endorsement of the National Committee for Development of Scientists and Engineers appointed by President Eisenhower. A grant of $10,000 has been obtained from the National Science Foundation for the planning and development of the program; the actual study will be financed by a grant from a private foundation.

► . . . . That the only summer school this year is that of the Civil Engineering's Committee on Surveying and Mapping—the Fourth National Surveying Teachers Conference? It is to be held on August 4–9, at the Summer Surveying Camp of the State College of Washington, Camp F. W. Welch, Naches, Washington. This is the first national conference held since 1952, and President C. C. French of the State College of Washington has invited all surveying teachers to attend. For details, write to Professor E. G. Ericson, at Washington State.

► . . . . That Vice President W. T. Alexander represented the Society at the Mid-Winter meeting of the Co-op Division? He reports a very success-

ful session, with the largest over-all registration in recent years. The representatives from industry slightly outnumbered the representatives from colleges.

► . . . . That the third dues notices were sent out during February? They went to 153 of the 1657 members under 36 years of age ($6.00 per year dues), and to 612 of the 5294 members over 36 ($8.00 per year dues). In addition, 51 members owe $12.00 and 180 owe $16.00; these are the ones who will be dropped at the end of the fiscal year for non-payment unless they repair their standing between now and July 1, 1957. Of the 109 college and university institutional members, six have not yet paid; of the 136 associate institutional members, five are in arrears. If you are among the delinquents, how about paying promptly? About half of those receiving the second dues notice responded; it is hoped this third effort meets with greater success.

► . . . . That ASEE is cooperating with the EMC, SMC, NRC, and NSF in sponsoring a National Conference on the Problems of Engineering and Scientific Higher Education in Chicago on October 10–11? A closed planning conference of about twenty-five leaders of the organizations mentioned above and a few others was held at the Gould House of New York University on January 13–15. This April conference will be directed to the general public as well as to state and federal government, giving a factual presentation of the actual situations and pin-pointing the consequences of failure to act effectively and quickly.

► . . . . That the National Committee for the Development of Scientists and Engineers is devoting its major efforts to two extensive and significant problems? They are: (1) ways and means of increasing the number and improving the utilization of technical and semi-professional persons whose skills support the work of engineers and scientists, and (2) ways and means of encouraging the revision and enrichment of elementary and secondary school curricula in science and mathematics. Nine working groups have been established to study and report on various aspects of the two problems.

► . . . . That the newly formed Council for Basic Education has a grant of $114,000 from a non-profit foundation, and proposes to initiate and support measures which will insure, among other things, that all students receive adequate instruction in the basic intellectual disciplines, especially English, mathematics, science, history, and foreign languages.

► . . . . That a nationwide campaign to increase public interest in and support for higher education is to be conducted by the Advertising Council? Volunteer services and facilities contributed by advertising agencies, communications industries, and national advertisers will be utilized. The program is sponsored by the three-year-old Council for Financial Aid to Education.

► . . . . That you should make your plans now to go to Cornell in June?

W. Leighton Collins
Secretary

ENGINEERS AS MARGINAL MEN

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Engineers comprise a remarkable segment of American society, at once the most conservative and the most revolutionary. Perhaps because of their respectability as citizens, they have received far less public attention than is warranted by their social role. Their divorce rate is low, their crime rate almost negligible, their children rarely delinquent. Most of them vote Republican, and nearly all of those who do not vote Republican, vote Democrat. Nonetheless they are revolutionary and marginal.

The term "marginal" was first used (1) to describe the cultural situation of the children of European immigrants. Immigrant parents usually retain many of the customs, beliefs, and values of the society from which they came. They are likely to live in a colony of their fellow countrymen in one of our large cities, and the colony retains many of the old-world traditions.

Their children, however, are subjected to the new values and ways of America—in school, on radio and television, through contact with Americanized children, and at movies to which they go without their parents' knowledge. These children continually find themselves in situations where they must choose between the demands of their parents and the demands of their American friends. Standards of religious observance, dating rituals, domestic activities, and so forth are different in the two cultures, and the young person is placed in considerable conflict.

Engineer Torn Between Cultures

In general the marginal man is a man torn between two cultures whose value systems are in some respect incompatible. In this sense the engineer too is marginal. His marginality derives from a peculiarity of his profession; the two cultures to which he is marginal are the scientific culture and the business culture. The engineer's case is, however, if anything more severe than that of the traditional "marginal man." His is more like the marginality of the child of intermarriage where mother has one cultural background, father another.

The greatest point of difference between the engineer's occupational parents lies in the reasons they see for doing anything, and as a result, the sorts of things they consider worth doing. Business traditionally raises the question: Is it profitable? Science usually asks: Do we know enough about it? If it is not profitable, the businessman will not be interested in doing it. If quite a lot is known about it, the scientist will not be interested in doing it. The engineer has a third question which he has devised to maintain family harmony: Can it work better?

Business vs. Science

A second difference between the parents is in their time perspectives. The businessman demands that a project earn a profit *this* year. The scientist demands that we keep working until we know all we do not know. The engineer tries to mediate by asking the businessman for a little more time, and by asking the scientist to hurry up.

The engineer tries to get along with his parents, and occasionally the parents try to get along with each other. But this usually means an agreement on which one is wearing the family "pants." There is at least one company where the production and marketing people wait for the scientist to produce a crumb that is worth producing and marketing. They persuade competent scientists to join the organization, and once in a while they ask "Have you anything for us?"

More frequently, however, business wears the trousers. For example, some companies have operations research groups. Operations research defines the operations of the business as respectable objects for scientific research. Whatever the business does, the operations research group worries about. This is a case where the scientist treats the businessman's problems seriously.

The engineer, of course, takes everybody's problems seriously. But even so he gets into trouble. Sometimes his question "Can it be made to work better?" is well received by businessmen. Companies that make machine tools they use themselves demand good engineering. Where the relation is directly with the market, however, the question of profit can lead to frustrations for the engineer.

For example, a firm in the textile business installed an automatic machine to straighten the cloth because of complaints from their customers. The engineers had originally recommended the cloth straightener, but noted that the machine to which it was to be attached stood on such shaky foundations that vibration would make the straightener useless. Naturally they wanted to haul the machine up and put it on a concrete base. The manager, however, showed no interest. He had obtained the desired results. He was able to show his customers that he was now using the latest in cloth-straightening equipment: this reassured them and they continued to buy.

The engineer can get into difficulties with the scientists, too, particularly when he encounters a strange phenomenon which needs intensive study. There is, for example, the case of the disappearing additive. This was added to oil at one end of a pipeline, but when the oil came out the other end, the additive was gone. What had happened to it? The engineers had no answer. But when they applied to the scientists they were told: "Sorry, we're busy—a long-range program. Maybe we'll learn something about the adsorption of additives as we go along. Perhaps that is not what is causing your difficulty anyway."

In sum, this means that for the engineer, life in industry is not a bed of roses. There is even some name-calling, of the kind where father says, "You're as bad as your mother," and mother says, "You're as bad as your father." If the engineer shows more than a "fix-it" interest in an industrial problem, the businessman is likely to

refer to him as a long-hair or prima donna. If he shows no interest in science and prefers to "cut-and-try," the scientist regards him as a technician, mechanic, or maintenance man. Perhaps the most devastating type of comment was made by a director of research who maintained that the best way of getting results from scientific research is to hire good scientists, give them whatever they want, and wait. When asked if that is what is meant by "directing research," he replied: "Look, if you give orders to your scientists, you just end up with a bunch of engineers."

Engineer's Social Responsibility

Yet the engineer bears a heavy social responsibility, and bears it well. The knowledge collected by scientists does not automatically transform itself into something useful to society. In the form in which it is expressed by scientists, its usefulness is limited to the purposes of scientists. Like a parish priest, the engineer is the link between the monastery of science and the secular world of business.

This engineer's role as channel has become increasingly important as science has progressed. The great accumulation of codified knowledge, together with the development of a cult of scientism, has served to cut away the direct communication links which may once have existed between scientist and layman. The faith that knowledge is good for its own sake—a belief on which the founders of the Royal Society did not express any positive opinion (2)—makes it possible to ignore the question of the broad social consequences of new knowledge.

The development of languages suited to the nature of the scientist's data produces unintelligibility, and unintelligibility is further maintained by the fact that popularizing of science is not a very respectable activity. It is, of course, incumbent upon the scientist to communicate his findings to his colleagues. The broad social value of his work is less a subject for consideration than its narrow social value—that is, service of his colleagues and attaining a respected status among them. Within the scientific circle, there must be no secrets.

Thus the scientific society acts as if it were a closed society, the product of each member's work being intended for the consumption of the other members. Traffic with the outside world is frowned upon. Within the group, the growth of knowledge is circular; what one does stimulates another, and so on until all know a great deal more than when they started.

Perhaps if scientists could be supported without any expectation of a return on the investment—as it may be argued is the case with monasteries—science could remain a closed system to the greater contentment of those inside it and those outside it. But it is just this inward orientation of scientific groups which has led scientists into some difficulties with the general public. There seem to be both distrust and awe—Bronowski says hate (3)—of scientists in America, by no means derived from their actions in the past. Its basis seems to be the fear that scientists might become irresponsible. They do not conform to the established values of society. They know things they do not tell the public. Might not this knowledge be turned against society?

The scientist is sometimes a hero in books and films, but more often he is a villain. It is interesting to note

that on the most dramatic occasion when scientists openly shouldered social responsibility, they had reason to regret the experience. Oppenheimer has noted that since the first atom bomb, scientists have suffered from a sense of sin. The temptation is to retire to the closed circle of the esoteric laboratory again, since the demonstration of a most devoted sense of social responsibility backfired.

Engineer's Social Role

This digression into the marginality problems of scientists provides a background for understanding the engineer's social role. The engineer is the principal leak in the scientific vessel. He is the willing translator of scientific knowledge into the intelligible medium of equipment for social use. The lay public does not read the professional journals, and would not understand them anyway. It is the engineers who ferret out the knowledge which can be turned to social use.

But looked at from the other side, the engineer is not merely a leak in the scientific vessel. Or let us say that, through the engineer, the scientific vessel can be leaked into as well as leaked out of. Engineers provide new problems for scientists, since the application of knowledge in new environments itself raises new questions. Without the engineer, science might well degenerate into a casuistic activity akin to the monastic labors of medieval times. Pure mathematics, to be sure, has something of that character today, because it has to do with possible and impossible realities rather than with historic events.

Because of their strategic position between the source of new knowledge on the one hand, and the production of equipment for social use on the other, the engineers are the most effective revolutionaries in our society. Without them the rate of change would be slow indeed. This rate of change is not measurable in economic terms alone—the three per cent per annum estimate of increased productivity attributed to technological growth.

It is much more difficult to measure the changes in religious, political and moral beliefs, patterns of living, values, aspirations, and class identifications which a rapidly changing technology carries in its wake. We are impressed by radio and television, though they hollow out our language and fill our lives with discontinuities. We are delighted with modern means of transportation, though they speed the decay of some ancient means of social control.

The continuous revolution wrought by changing technology is the work of engineers. Yet the revolutionary engineer is no subversive citizen. He upsets the established order while acting politically as a conservative, and privately as a middle-class family man. Is he then leading a double life; a revolutionary from nine to five, a respected citizen in the evening? Certainly not, as far as his own sentiments and beliefs are concerned. He is a responsible employee at work, a sedate parent at home. Yet he upsets the social order.

The engineer can reply that his goals and values are no different from those of other Americans. The belief in progress, especially technological progress, is a vital element in our culture. Engineers are not revolutionaries; they are abiding by a dominant American value. This is of course true; but that

technological progress in turn creates new social problems is such a compelling fact or our times that this particular "truth" only settles the matter if one deliberately ignores the evidence.

Alternatively, the engineer can choose to refer to particular patterns of social results to justify his political conservatism. For example, it can be argued that technological innovations are encouraged by management when labor, by such means as collective bargaining, begins to receive a greater proportion of income from existing technology than management has traditionally regarded as desirable. By creating a labor-saving innovation, therefore, the engineer is helping to maintain the *status quo* with respect to the distribution of wealth and power in industry. It can scarcely be maintained, however, that the social system is in all respects so nicely geared to innovation.

Sounder Position

A sounder position for the engineer to take would be that, although there is no denying the existence of connections between technological and social change, the effects of specific technical innovations, or of the sum total of engineering activity, are so unpredictable that it would be futile to worry about them. In the present state of knowledge, it is impossible to predict whether all or some of the long-run effects of an innovation will be good, or all or some of the short-run effect bad, or vice versa, or both good, or both bad.

Neither can we say whether the criteria of good and bad will remain unchanged. Only if the engineer believes that *any* great social, cultural, economic, or political change is of itself good or bad can he take a clear-cut stand. If he thinks all such change is good, he can afford to be carefree; if he thinks all such change is bad, he should retire from his profession.

When the secondary effects of actions are so unpredictable, the normal human reaction is to lower one's sights, attend to the immediate effects, and work in terms of the part of the future which is clearly foreseeable. The engineer is rewarded for engineering. Society is a remote judge; there is a more immediate, more personal judge, in the form of the engineer's boss. He pays the bill. The engineer's social responsibility is to give honest value in return. Beyond that, let the boss decide. He has more criteria at hand for estimating the results of alternative courses of action.

Now this seems a very strange attitude for a person who is, in terms of the effects of his actions, a revolutionary. His personality does not appear to match his social role. But it is psychologically easier to adopt this attitude than to attempt to base his actions on consequences which are beyond his power to predict.

This psychological account of the engineer's attitude can be supplemented with a more sociological one. The engineer is an innovator, sometimes an inventor, in the long run a revolutionary, but his personality does not conform to our expectations. There was a time when the innovator had a personality to match his innovating activity. The man who desired change, who tried in the face of conservative society to bring it about, was a restless, often neurotic, individual. When we think of an in-

ventor, we think of unusual personalities: Edison, Fessenden, Marconi (4). Their lives were a mess financially, or socially, domestically, or politically. Gillette, who invented the safety razor, wrote three books containing plans for a new world order: a utopian, supersocialist society living under one World Corporation (5). There are still such men around, some of them engineers. But the great changes in our way of life are made by men whose lives are not irregular, who conform quite closely to the standards of established society.

Why do these modern change-agents not resemble the ones of fifty years ago? The answer seems simple enough: engineering, or the introduction of change into the conditions of living, has become institutionalized, and engineers along with it. Establishing a respectable, rewarded role for the engineer, creating a great educational and employment system to provide him with a kind of cradle-to-grave security—all this has provided a route along which the well-adjusted citizen can travel and make changes in the conditions of living just as great as the erstwhile inventor who, deviant and maladjusted, was driven to a life of change-making. His work had great personal significance for him. But the modern institution of engineering has lost that meaning for its members. The engineering student learns to seek high grades on examinations and a job after graduation.

These gloomy remarks are reminiscent of the concerns of those odd apostles who thirty years ago chose Veblen as their Messiah—the nearly extinct sect called Technocrats. But there is a brighter side to the picture, a sense in which Technocracy's dream is being partially realized, though certainly not in the anticipated manner. Engineers are becoming more powerful socially.

That is, the power of individual engineers, not engineers' power as a class or organization, is increasing. The engineering associations have no economic power beyond restriction of entry through the maintenance of standards. And gaining power through unionization is shunned as "unprofessional." But an ever-increasing proportion of managers is being drawn from the ranks of engineers.

This trend has been accompanied by a proportionate decrease in the number of managers who are primarily merchants or financiers. It has also been accompanied by an increased concern on the part of industrial management about "social responsibility." The social, economic, and political changes of the past century, together with changes in the internal organization of industry, have helped to focus attention on management's social role.

The concomitance of these trends may be sheer coincidence—though careful workmanship, a desire to do the job better, and to be of use to his fellow men are common characteristics of engineers. Being a "lion" rather than a "fox" does not insure the social good, of course, and doubtless some of the worst examples of labor relations in the country can be attributed to the administrative judgment of engineer-managers.

The idea that engineer-managers are playing a powerful role in shaping American industry receives some support by comparison with a country where engineers are only beginning to attain positions of prestige and power. Britain's postwar indus-

trial and economic difficulties were blamed on trade associations, labor unions, taxation policy, and socialism, among other things. Perhaps a more fundamental problem was that industry was still under the control of foxes rather than of lions.

There were British editorials commenting on the laziness and ineptitude of management, and recommending that managers be trained to comprehend and take advantage of advances in technology. On reading such editorials, the American is tempted to ask: Where were the British engineers? The answer is simple: they were right there, but underneath. The vital difference seems to be that in most British companies they stood practically no chance of rising to positions of power.

Engineers in Power

Thus the rise of some engineers in America to positions of obvious social responsibility is the bright side of the picture, and the tendency of other engineers to let the boss carry the burden of the less obvious social responsibility inherent in their profession, the dark side. Engineers do not really like the latter state of affairs: attitude surveys show them to be the most dissatisfied employees in industry (6). And other surveys indicate that the vast majority of them want to become managers (7). Evidently the rise of some to central positions does not decrease the marginality of the rest.

As industrial procedures become more technically complex, the engineer's organizational role inevitably becomes more central. In terms of organizational requirements, therefore, its cultural and psychological marginality are anachronisms. This lag has unfortunate consequences for professional responsibility and satisfaction. And the cause of the lag must lie either in a stereotype of management which prevents the sharing of responsibility and recognition, or in inadequate professional education which makes the engineer untrustworthy as a responsible member of the organization.

BIBLIOGRAPHY

1. E. V. Stonequist, *The Marginal Man* (N. Y., Knopf), 1937.
2. R. K. Merton, "Puritanism, Pietism and Science" in *Social Theory and Social Structure* (The Free Press: Glencoe), 1949.
3. J. Bronowski, "The Real Responsibilities of the Scientist," *Bulletin of the Atomic Scientists*, Jan., 1956.
4. W. R. Maclaurin, *Invention and Innovation in the Radio Industry* (N. Y., Macmillan), 1949.
5. G. B. Baldwin, "The Invention of the Modern Safety Razor: A Case Study of Industrial Innovation," *Exploration in Entrepreneurship*, Dec., 1951.
6. D. Moore and R. Renck, "The Professional Employee in Industry," *Journal of Business*, Jan., 1955.
7. H. A. Shepard et al., "Field Studies in the Organization and Management of Research," MIT, mimeo., 1953.

Annual Meeting, June 17-21, 1957

VOICE FROM THE OTHER SIDE OF THE TRACKS

L. B. ZYLSTRA

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"I am sending herewith a paper that I would like you to consider for publication in one of the forthcoming issues of the ASEE JOURNAL. I realize that this material is of a rather controversial nature and feel that it should get some attention. This should fit in with your editorial policy stated in the January, 1956, issue, 'There should be room in the JOURNAL for discussion, comments, and for differences of opinion leading to profitable sessions at subsequent meetings.' There has been considerable material published in the JOURNAL in criticism of the type of courses discussed; we at the University of Washington feel quite strongly that material in rebuttal is very much in order."

When the writer registered for the recent Northwest Regional ASEE Conference, he was asked to note his field of major interest to facilitate seating arrangements at the "Common Interest Luncheon." He wrote: "Production Methods." At the luncheon he found himself seated with five men who were vociferously machine design teachers, plus one who failed to make his interests known audibly and who, therefore, may have been a teacher in the field of manufacturing processes. He assumed from this that the seating committee either (a) chose, out of kindness to a colleague, to ignore the expressed interest or (b) could not find a sufficient number of registrants admitting such an interest to fill a table.

During the past five years, there has appeared an increasing tendency on the part of engineering educators to view as an "educational pariah" anyone associated with, or evincing an interest in, the teaching of courses in manufacturing methods. Unfortunately, this is not a local situation but is fairly widespread. This group of courses is today regarded by many engineering educators as a poor relative whose existence, if countenanced at all, is not discussed outside the immediate family.

These educators are primarily those who have had no experience as practicing engineers or who have been so long removed from this experience that memory has been obscured by time. In many cases, the latter unfortunately include some whose years and seniority have elevated them to positions of authority. This trend, history tells us, has been occurring in cycles with sine-wave regularity during the entire history of engineering education. A patient person should wait for the peak and subsequent recession, which by all evidence is near at hand.

The writer, however, views with considerable concern the degradation, and even loss in some cases, of this group of courses from the M.E. and

I.E. curricula at some very good institutions. The lowered quality of engineering graduates, together with the problem of rebuilding these courses when the shift sets in the other direction, leads the writer (never a man of great patience, and one who has borne up under epithets worse than "educational pariah" in his varied career) to express his views.

One point should be clarified at the outset. The writer does not take exception to the recent recommendation by ECPD to the effect that "shop courses, etc., should be critically examined. . . ." He chooses rather to assume that this recommendation was aimed at the elimination or alteration of shop courses taught on trade-school principles.

Most readers will be familiar with courses such as these, typified in the extreme cases by requiring many laboratory hours occupied by the student in the chiseling-filing of a cube or a D-slide valve from a block of cast iron. The course may be taught by a journeyman machinist who had performed the same tedious "exercises" as part of his apprentice training.

Courses such as these are still taught as "engineering" in many otherwise first-rate institutions, except that the chiseling-filing is now generally done by machine tools. It is the writer's contention that these courses should be abolished, not only because they are valueless but because they are the "shop courses" responsible in large measure for the opposition to the teaching of manufacturing processes in any form.

As opposed to the above type of course, look next at the situation at the University of Washington. The manufacturing processes group has developed tremendously in the past twenty years, in size, in number and variety of courses taught, and in value to the engineering student. This development occurred under the guidance of Professor Gilbert S. Schaller, with the complete approval and assistance of department head and dean. The staff for this group consists of a professor, two associate professors, two assistant professors, and two instructors. These men are engineers. They can, and on occasion do, teach many other courses in the M.E. curriculum.

Basic Courses

Let us look next at the three basic manufacturing courses, since they are the ones most frequently subjected to criticism. These we will call foundry, welding, and machine shop, regardless of what they are termed in the catalogue. They are taught here, in the order named, as sophomore level classes.

Most people will agree that the primary reason for the employment of 99.9% of our engineering graduates is their ability to contribute some share in the manufacture of a product that can be sold at a profit. If this is accepted as the, or one of the major objectives of an engineering curriculum, we can compare the education of an engineer to a pyramid. The apex is the product. The broad base consists of the sciences upon which we build with such courses as mechanics, thermodynamics, structures, machine design, humanistic studies, electric circuitry, fluid flow, and metallurgy. On top of this essential foundation should be placed the processes group which, finally, makes the engineer aware how this mass of knowledge is to be used to accom-

plish the ultimate objective, manufacture of a product to be sold at a profit.

If a course contributes a good share in this ability, it has a legitimate place in the engineering curriculum. Our three basic courses are taught with this in mind. It is felt here that no engineer, regardless of his field of major endeavor, can function as well without knowledge of manufacturing processes as *with* this knowledge.

To the question, "How can a man design anything intelligently unless the design and material selection are made with an eye to the manufacturing process?" we must answer, "He can't." A. M. Nelson, a former classmate of the author, and now in charge of a fairly large research organization devoted largely to design and development of electronic equipment, recently made a statement along these same lines. He said, "Idea men, I've got dozens of them and they really function, but I'd trade an even dozen of them for one who had included in his education a thorough knowledge of manufacturing processes."

He went on to cite examples of cases where his "idea men" had spent large amounts of time and money designing and developing ideas that turned out to be either impossible or impracticable to manufacture. The writer feels he can state without reservation that these men had never *experienced* the capabilities and limitations of modern manufacturing processes. Some had taken the trade-school type of courses, had received nothing of value from them, and had been glad when they were finished. Others had received instruction in manufacturing processes conducted as straight lecture courses.

Mr. Nelson's education, on the other hand, was obtained in an institution where processes were given considerable prominence and where the limitations of the spoken word and visual aids were countered by actual laboratory experience in the use of manufacturing facilities. He knows the limitations and capabilities of both company and outside facilities, and is daily forced to waste considerable time attempting to intercept and steer the efforts of his "idea men" along the proper lines. The writer's contention is that his men, if they were to be called engineers, should also have known these things.

The basic objective of the three courses mentioned above is this: To help the engineering student (the engineer-to-be) make a wise selection among the manufacturing processes available for a particular product. After completing the series of courses the student should have developed a critical frame of mind, an altogether different manner of thinking, regarding any manufactured object that comes to hand. He should mentally criticize any product he sees, asking himself these questions: Was the material selection right? Could the design have been improved? Was the right manufacturing method used? Was the selected method properly carried out? If the student has been properly instructed, these criticisms should be made, only with a full knowledge of how suggested changes would affect the product in terms of the factors by which a potential customer will judge it: (a) Its ability to perform its intended function. (b) Its quality—including such intangibles as appearance, "feel," noise, etc. (c) Its cost. (d) The manufacturer's ability to deliver on time.

If the above frame of mind has been developed by the three courses

mentioned, the program has been successful. It is admitted that this objective is more difficult to accomplish at the sophomore level than at the junior or senior level. The sophomore tends to accept industry and its methods as being above his criticism, whereas this tendency has been somewhat dissolved by his senior year. The program here is not yet at that stage in its development, however, so it remains at the sophomore level for the time being.

For Example

As a concrete example, let us take a lecture on casting design in the Metal Castings course and see how this is taught in order to progress toward the above objective. Previous considerations have been duly weighed that pointed to casting as the process and gravity casting in a green sand mold as the specific method. The instructor selects the object, preferably simple, and leads the class members through its design. They come up with perhaps three design possibilities that are essentially equal as far as function is concerned.

Assume that the object is a simple "V" groove bench block and that we have the alternatives of designing this as a solid casting, a hollow casting with the working surface supported by a skirt having its lower edge "turned out" to provide a supporting surface, or with the base "turned in," requiring the use of a dry-sand core. The class will then consider the effects of these design changes on the factors mentioned before. Some of the specific considerations would be: cost of patterns for each of the three designs, cost of feeding the first design to compensate for solidification shrinkage, cost of core box and cores for the third design, comparative molding costs, adaptability to machine molding, cleaning costs, and machining costs.

The patternmaker would then make patterns for each of the designs and during the subsequent laboratory work these would be molded and cast by the students with various available methods, the castings sectioned, examined, and tested, and rough comparative cost estimates made on the basis of actual laboratory work.

The lecture material connected with this phase would also include, of course, those principles of casting design not brought out by the example chosen. The method of instruction exemplified above is also carried out through the other phases of the course, and is followed where possible in all basic courses. The value of this type of instruction should be apparent; it is evidenced by the thinking patterns of the students who have received it and by reports from our graduates and their employers.

No engineering school today can afford to sacrifice any of the students' time to courses that are taught merely for the sake of tradition. Realizing this fact and spurred on by the enjoinder of the ECPD, many educators are looking askance at their antiquated "shop courses." Unfortunately the tendency seems to be to chop them off rather than to modernize them to what they should be. At the University of Washington only about 2% of an M.E. student's time is spent in required production courses and still less amounts by majors in other departments. This is obviously not enough time to make molders, welders, and machinists of anyone. This is not even enough time to attain thoroughly the objectives previously men-

tioned but, at least, the objectives have been defined and the attempt is being made.

If the term trade-school were to be applied to our production courses, it would be deeply resented by all in our department. We sincerely feel that the value of these courses to the operating efficiency of the graduate engineer more than balances the small allotment of time in the curriculum.

It seems incredible that there can be more than a few isolated engineering educators who are shortsighted enough to maintain that such instruction is not engineering and has no place in engineering education. These men, however, when they are in positions of authority, can do themselves, their schools, and industry an incredible amount of damage before the top (or bottom) of the cycle is reached and the trend again sets in the opposite direction.

NEW AEC TRAINING PROGRAM

The Atomic Energy Commission has selected six universities to participate in a program designed to double the number of nuclear reactor specialists trained each year at the Oak Ridge School of Reactor Technology. The universities, selected from among 44 which submitted proposals in October, on the basis of being the most suitable to meet the present short-term needs of the ORSORT program, are the Carnegie Institute of Technology, Pittsburgh; Case Institute of Technology, Cleveland; Northwestern University, Evanston, Illinois; University of California at Los Angeles; University of Florida, Gainesville; and Union College, Schenectady.

Two-year contracts will be negotiated to provide for concentrated courses of study intended to develop specific proficiency in chemistry, mathematics, physics, and engineering for students accepted for ORSORT. Under the new expanded program, the first six months of the one-year course will be given at the participating institutions, and the remaining six months at the Oak Ridge National Laboratory. This arrangement will permit two classes of 120 students each to be trained per year, while currently only one class of 120 students can be accepted annually because of limited facilities at the laboratory.

SCIENCE AND LIBERAL EDUCATION

ESTILL I. GREEN

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Adapted from a commencement address at Westminster College, Fulton, Missouri, May 28, 1956

As we look today at science and liberal education, what do we find? An odd situation. A paradox, if you will. While scientific change moves with seven league boots, or seventy times seven, science and liberal education are not coming closer together. They are not even, like parallel lines, pursuing paths that come together at infinity. They are drifting apart. Many thoughtful observers discern an increasing lack of interest and understanding by each for the other. As a result, certain myths or half-truths seem to find a growing credence, not only by the general public, but also to degrees by more educated people.

A few examples of such myths were noted some time ago in a talk by Dr. Warren Weaver to the American Association for the Advancement of Science. Let me borrow from, and supplement, Dr. Weaver's listing (Ref. 1). In popular fancy, there seems to be nothing, at least of a physical nature, that science cannot do. It can, so rumor goes, produce a universal cure for every human ailment. It can prolong life indefinitely, or even create it. It can transport people in space ships to any part of the universe. It can reverse the flow of time. And so on indefinitely.

Peculiarities of Scientists

The scientists who have the ability to accomplish these miracles are conceived as being different from ordinary people. They live in a world of their own. They are devotees of a strange cult whose motivation is a mysterious something known as the spirit of science. Their sole aim is to wrest truth from nature, and whatever effect their contrivings may produce upon society is of no concern to them.

Moreover, they say, ordinary people cannot understand either science or scientists. Both are too complex. Hence both must be taken for granted. If anything, science is less baffling than its practitioners. The only sensible attitude, clearly, is the one taken by the colored story-teller when asked about the terrapin. The reply was a gem of simplicity: "I don't have to 'splain what make him do like he do do."

Now, if we look on the other side of the fence, what do we find? Scientists, being human, have a few misconceptions and half-truths of their own. Indeed, these bear a considerable resemblance to the ones we just mentioned. Ordinary people, say the scientists, do not understand the nature of science. They find its products convenient and congenial, but they have no gratitude toward their benefactors. All they want is to exploit the scientist, to use him for their own ends, like some strategic material. Moreover, so legend goes, sci-

entists are different from ordinary people. They are dedicated to physical truth. Science has its own moral code. Scientists are above the rules of society. And so on and on.

A nice trick in mathematics is to carry things to extremes and see what happens. So I have found it convenient to state these myths and half-truths and muddy understandings in their extreme form. Naturally there is a wide range in degree of acceptance. But this is not all fairy tale. You can find chapter and verse in both public press and technical press. Or if you want the real low-down, just talk with people. You will find many people like the White Queen. They just take a deep breath and believe six impossible things before breakfast.

Science in the Secondary Schools

To the extent that ideas such as these exist, they are symptomatic of a widening gulf between science and general education. But if we are to understand the situation, we must dig deeper into underlying manifestations and causes. Suppose we start in the secondary schools (2). Some day I am going to write a mystery story. The scene can be laid in almost any high school in the country. For a title I will choose something like this: "The Case of the Missing Science Pupils."

The facts of the case are simple. In 1915 about 60 per cent of the pupils graduating from high school had taken a course in physics. By 1955 the figure had dropped by ⅔, that is, to less than 20 per cent. Chemistry, starting at a much lower level, has barely held its own.

Meanwhile, something new has come into being, a hodgepodge course known as general science—a confused jumble of astronomy, chemistry, physics, geology, meteorology, and so on. But even if you count this in, high school training in physical science fails completely to measure up, either as a breeding ground for scientific talent or as a mere briefing for non-scientists in a scientific age. It must have been science lessons that the Gryphon was talking about in *Alice in Wonderland.* "That's the reason they're called lessons," he remarked, "because they lessen from day to day."

And mathematics, that handmaiden of science, that unexampled exercise in logical thought, what about it? Alas, it too has come upon evil days. Today the percentage of high school students enrolled in math is less than half what it was in 1915. In any contest to decide which subject is most disliked by the pupils, math almost always wins.

Stemming out of this secondary school situation is the much-publicized shortage of scientifically-trained personnel in this country. This is indeed a source of grave concern, and is fast getting worse.

But the crime trail leads on. Not only is there an ominous scarcity of science pupils in high school; the dearth of qualified science teachers is equally or even more disturbing. Their number has dropped more than half in the past five years. To some extent this is part of the general situation of underpaid public school teachers struggling to maintain their social status. But both shortages—of science teachers and of science students—are, I think, symptoms of a deeper unhealthiness. The interest of young people in science, the quality and quantity of science teachers, the attractions of scientific careers, all

these are strongly dependent on the attitude of the general public toward science. The real difficulty with science in the secondary schools, is, I believe, a lack of understanding and regard for science on the part of the general public.

Science as a Part of Liberal Education

How shall we go about developing such an understanding among people? There is, I think, only one answer—through liberal education. As Dr. J. A. Stratton of M.I.T. has pointed out, it is the educated people of a nation that determine its intellectual character (3). So it is to the body of educated people, mostly non-scientists, that we must look for any modification of the popular take-for-granted attitude toward science. We come back, then, to liberal arts training in the colleges and universities.

I think it is no exaggeration to say that if we are to survive as a free people, science must be made a more vital part of liberal arts training. To me this conclusion seems especially appropriate when I recall the meaning of liberal arts. Originally they were the *"artes liberales,"* the arts which, among the Romans, only the *"liberi,"* the free men, were permitted to pursue.

When we say that science must become a more vital part of liberal arts training, what do we really mean? Not a review of the history of science. Not a smattering of scientific formulae. Not a science hodgepodge. First of all, we mean a true understanding of the scientific approach, a familiarity with the great struggle waged by Galileo and his successors for the then new principle that in scientific judgment observation and experiment are the courts of final appeal.

Other things essential for a truly liberal education are these: an understanding of what science can and cannot do; a comprehension of the contribution that logical, scientific analysis might make to social advance; and a realization of the tremendous power of the simple words "how" and "why." Moreover, liberal education should learn the language of science. Not all of its "lingo," by any means, but a basic vocabulary of scientific terms and an appreciation for the beauty of precise terminology.

Also, liberal education should embrace an understanding of the process of creative thought. This process is not esoteric. It can be understood. Creative ability can be enhanced by training. Indeed, creative thinking is now being taught at a few schools. Such courses should indicate the basic similarity between creativity in the arts and in science, and should trace the steps in the creative process. In fact, a little practice in common-sense thinking might be thrown in for good measure.

Until it encompasses a greater measure of such concepts as are required for a true understanding of scientific advances, liberal education will, I believe, lack full relevance to our modern world. Up to now our liberal education has comprised in considerable degree a classical kind of culture. Without sacrificing the important elements of this, we need to develop a modern culture, with science inherent and in proper balance, not elective and neglected. Can so-called "liberal arts" students be really liberal, keep themselves correctly oriented in this changing world, without

cultivating a growing awareness of science?

The Plight of Science

If up to this point I have seemed in any way critical of liberal education, let me now have a go at science. As we have seen, science is in a pickle. It is out of touch with people, and it is unable to keep its ranks filled.

The blunt truth is that this pickle is largely one of science's own making. Rejoicing at the privilege of walking within the veil of the temple of nature, and beguiled with their own devices, too many scientists have withdrawn themselves too much from the problems of society. Furthermore, technical specialization has grown and continues to grow apace. In fact, many scientists have become so specialized that they frequently don't understand one another, let alone non-scientists.

Some of my colleagues might have a comeback for this, a comeback just as good as the one that Winston Churchill had for George Bernard Shaw. Shaw was putting on a new play, and sent two tickets to Churchill with a note: "Bring a friend if you have one." Churchill replied: "Can't be there for opening night. Will attend second night if play lasts that long." But in the absence of some rebuttal, it is hard to escape the conclusion that scientists need a better understanding of people.

A Mutual Opportunity

And now just see what a lovely situation we have uncovered. Science and liberal education can confer great mutual blessings. Each can round out the other. Science can give liberal education a broadened outlook. Liberal education, on the other hand, can give science a human and spiritual outlook. The French have a word for it—*rapport*. What we need is a closer *rapport* between liberal education and science.

This game of rapport is one we all can play. Each of us in his own way, as he finds opportunity, can contribute toward a modern, integrated, truly *liberal* culture, with science in due perspective. Here is our challenge as citizens. And only as we measure up to this challenge can we achieve the full promise being opened up by new technology.

The Technical Prospect

Electronic computers stand ready to relieve the human brain of routine for more creative tasks. Before long, machines may be able to perfect complex engineering designs, check them for soundness, prepare manufacturing information, and verify the performance of the product. Thus perhaps they will help to relieve the shortage of engineers.

Similarly, the system which people call automation, using suitably programmed controls to make machines run themselves, is effecting enormous increases in productivity. New communication systems are enabling machines to talk to one another in their own language of high speed pulses.

By enlarging the skilled teacher's audience, television has already made a start on relieving education's crisis. Indeed, experts predict that education is due to become the biggest and most important user of television equipment.

Atomic power does not have to be an agency of destruction. It can be an untold blesing. Today we use uranium fuel at a cost of $11,000 a pound. Some day sea water or ordi-

nary rock will serve as fuel. What this will mean to underdeveloped areas I leave to the imagination.

Our Challenge

We could go on into the fields of biology and medicine, of chemistry and metallurgy, and many another. Just to sum it all up, science offers the clear possibility of vast enhancement in man's lot. Meanwhile man faces a triple threat: annihilating war, vanishing natural resources, and a surging world population that will, unless it is somehow checked, multiply 2½ times in the next hundred years. Solution of these problems cannot be long delayed. Of course, science can help to find some of the answers.

The real basis for man's survival and well-being lies, however, in a new culture. Somehow men will have to learn how to live in harmony and mutual understanding. Though we understand all mysteries and all knowledge, and have not love, it shall profit us nothing. The real objective can best be reached through developing a new culture, a liberal, homogeneous blend of knowledge, rationality, creativity, objectivity, mutuality, and spirituality. A new world is man's for the seeking.

REFERENCES

W. Weaver, "Science and People," *Science*, Vol. 122, Dec. 30, 1955, p. 1255.
W. C. Kelly, "Physics in the Public High Schools," *Physics Today*, Vol. 8, March 1955, p. 12.
J. A. Stratton, "Science and the Educated Man," *Physics Today*, Vol. 9, April 1956, p. 17.

1957 NATIONAL SURVEYING TEACHERS CONFERENCE

The Civil Engineering Division of ASEE will sponsor the Fourth National Surveying Teachers Conference at the Washington State College summer surveying camp, Camp Welch, Naches, Washington, on August 4–9. Further information can be obtained by writing to Professor Elvin G. Ericson, Civil Engineering Department, Washington State College, Pullman.

SELECTION OF ENTERING STUDENTS BY COLLEGES OF ENGINEERING

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A paper presented at the Southeastern Section Meeting of ASEE, April 5, 1956.

My topic presupposes that there will be more students applying for entrance to the engineering schools than we can accommodate efficiently, and that therefore there must be selection. I assume we know the statistics of population growth and trends in college entrance, so that we do not need to repeat the causes of student pressures to come.

What criteria should the engineering school use in selecting its student body? What should be the relative weighting of the various factors involved?

In what follows I shall present a high school point of view and overstate some points for emphasis, perhaps, or make inferences with which you cannot wholly agree. If so, I know you will correct the errors in the discussion to follow, and I shall enjoy rebuttal and clarification.

Character and General Promise

Undoubtedly the most important consideration in appraising a candidate for entrance to an engineering school is his character and his general promise as a student, an engineer or scientist, and a citizen.

But character, personality, promise—these are also very difficult to assess.

Perhaps the best evidences available are the total four-year record in high school and the confidential reports from the boy's teachers and principal. But since recommendations are necessarily subjective, they are difficult to evaluate.

In mentioning the total high school record I mean much more than the final marks in the various subjects. The record should include his interest, hobbies, extra-class activities, and the like. The record should also include some appraisal of the boy's environment—the moral tone, the culture, the aspirations of his family and the community which have shaped the growing boy.

Unfortunately, there is little objectivity in much of this and it is particularly difficult to apply these data in comparing candidates from different schools. However, the difficulty involved, and the relative unreliability of the data, do not make them of less importance. In the final analysis, the character and promise of the applicant must be deciding elements in the consideration of a candidate for entrance.

School Marks

A candidate's four-year record of marks in high school constitutes one of the more reliable criteria for judging his academic promise in engineering school. But such data must be used with discrimination.

For example, different schools have such widely differing standards that it is folly to judge the boy with the higher marks to be the better student, on this ground alone. Class ranking —where a student stands in his own graduating class—gives some indication as to the relative worth of his marks. Later I shall discuss some of the fallacies connected with class ranking as a criterion for college admission.

The four-year record of school marks is made much more reliable if it is accompanied by a record of standardized achievement test scores that back up the marks. I want to discuss the use of standardized tests in more detail later on, also.

A third consideration concerns the atypical student. The so-called "late bloomer" is one—the boy whose physical development in early adolescence was so delayed, or so prolonged, that his mental work and abilities were not displayed to best advantage during his freshman and sophomore years in school. There are many such, and we must learn to weight the later marks more heavily in such cases. There is also the boy who will make a fine engineering student as soon as he has mastered reading—the technics of rapid and understanding reading. The college may be well equipped to render this service and develop a successful student. There is also the one-sided fellow, who will work like a dog in favorite subjects or on favorite projects, but who is not to be driven to doing well in those in which he does not already have an interest.

Class Ranking

Colleges are prone to lay down rules as to the required class ranking of applicants—only those in the upper half, or top quarter of the graduating class to be admitted. This is an unwise rule to follow literally. Used with flexibility, however, it affords incentive for high school boys to do well and gives a valuable internally-relative criterion of ambition, industry, and ability.

But watch out in applying the same standard to *different* schools! Admitting only from the top half of the class in a school that sends perhaps twenty per cent to college is vastly different from applying the same rule to a preparatory school that regularly sends 90% or more of its graduates to college. The Educational Records Bureau states that "a student who ranks below ¾ of his classmates in the average independent school would probably rank at about the middle of a typical public school graduating class. One who ranked at the middle of his class would probably reach the upper quarter of an average public school graduating class." I think it is fair to state that similar differences, if not as great ones, prevail among the public schools themselves.

When interpreting class ranking, one should know not only what per cent of the graduates of a particular school enter college, but also what type of college is entered. Standards in colleges also vary. For the purposes we are considering here, it would seem that as engineering schools and better colleges or universities attract more graduates of a school, it will be safe to go farther down in the class ranking before cutting off a candidate.

The Intelligence Quotient

On an occasion when we were discussing the elaborate entrance procedures at Harvard, former President

Conant told us that he would be happy to use the intelligence quotient alone as the criterion for entrance. Of course he expected a high I.Q., and counted on his faculty's inspiring the gifted student to work and to succeed, however poor initial preparation might be.

But I doubt that the I.Q. alone is a sufficient criterion. In the first place, we must ask, *what* I.Q.? Because they vary—a Binet-Simon has much more reliability than an Otis-Self-Administering Test of Mental Ability and one must distinguish, therefore, between the individual intelligence test without verbal components and a group test depending on ability to read. As a matter of fact, an I.Q. should never be reported simply as such; it should be stated as an Otis I.Q. or a Kullman-Anderson I.Q., or a California Test I.Q., or whatever.

When the high school can furnish more than one I.Q. reading for a candidate, the report of the cluster of marks makes possible much more reliable dependence on the I.Q. It is also true, as we have discovered in elementary and high school, that a boy with normal I.Q. and ambition, drive, earnestness, thoroughness, and reliability is much better as a prospective success in life than the high I.Q. man without these qualities. Best, of course, is the combination of ability with drive.

Standardized Tests

Many of our high schools use nationally standardized tests to measure the achievement of pupils in several or all work areas. Those of us who are members of the Educational Records Bureau have a system that makes possible valid comparisons between students from different schools, different states, and even different sections of the country.

If you were to recommend such tests for adoption by schools from which you draw your students and if you planned to use the scores for admissions purposes, I would suggest the Cooperative Tests of the E.R.B., especially those in English, mathematics, and the sciences, as well as the familiar Psychological Examination, College Freshman Form, of the American Council on Education.

A word of caution, however, about interpreting percentiles reported on such tests. Note carefully what norms the school uses as basis for the percentiles. The Educational Records Bureau states that "an independent school student who ranked at the 25th percentile in his own group on a scholastic aptitude test like the A.C.E. Psychological Examination or on any of the Cooperative Tests (except foreign language) would rank at approximately the 50th percentile or higher in the public school group. In algebra and geometry, his percentile rank would be 10 to 15 points higher if he were ranked with the public school group rather than with his own. Therefore, his independent school percentiles would have to be adjusted upward from 10 to 25 points or more to make valid comparisons with the percentiles for public school pupils. Of course the differences would not be so large at the extreme ends of the scale."

Scholastic Aptitude Test

Undoubtedly the single best test of aptitude for college, and the one adopted by an ever-increasing num-

ber of the best colleges and universities, is the Scholastic Aptitude Test of the College Entrance Examination Board. The test has a verbal and a mathematical section with separate scores. The verbal section measures ability to read with understanding and discrimination, the comprehension of words, and skill in dealing with word and thought relationships. The candidate's score on the test depends on his ability to reason logically, on his vocabulary, and on his ability to combine ideas and draw correct inferences.

The mathematics section measures *aptitude* for handling quantitative concepts rather than *achievement* in the study of mathematics courses. The test presupposes arithmetic, a first course in algebra, and the elements of geometry. But it is intended to identify the student who can *apply* basic knowledge in working out solutions to *new problems* rather than the student who has simply memorized facts and processes.

As you know, the College Board tests are scored by machine and the raw scores are treated statistically in comparison with a fixed "standard group." This is done to keep the scores comparable from year to year. The average score is 500; the standard deviation is 100. Two-thirds of the candidates in the group get scores between 400 and 600; scores range from 200 to 800.

What scores should an engineering school candidate receive? Well, standards differ from college to college. At my school we encourage application to an engineering school if the boy has at least 500 on the Verbal and 550 on the Mathematics Section of the S.A.T.

College Board Achievement Tests

The College Board also gives achievement tests in mathematics, along with those in English, chemistry, and physics, for engineering school admissions. All these are one-hour reviews of high school learning. The Intermediate Mathematics Tests place emphasis on the ability to use what a student has learned in elementary and intermediate algebra (through quadratics and systems of equations), in graphical representation and corresponding equations, and in plane geometry.

This is the test recommended for use when the first courses in the engineering school will not include analytic geometry and the calculus.

But if the student is expected to start with analytic geometry and the calculus his freshman year, he should be prepared to take the College Board Advanced Mathematics Test his last year in high school. This measures his basic preparation for advanced mathematics courses and for the study of the physical sciences in college. It includes questions in trigonometry, in solid geometry (especially mensuration and the relationships of lines and planes) and more advanced topics of high school algebra.

Advanced Placement Tests

I should like to mention something new in the preparation of gifted students in high school. A few schools are now engaged in the Advanced Studies program, with the intention of helping the really able and interested student, not to get into college

earlier, but to arrive much better prepared, able to advance through the undergraduate years into master's and doctoral studies more effectively and more rapidly.

The national program of Advanced Studies concerns high school courses in eleven fields, including chemistry, physics, and mathematics. The College Board is now giving an entirely new type of examination in these fields, for use by the colleges. Successful students are expected to be placed in sophomore year studies in their fields of excellence, and thus can get ahead faster with their study in fields where they surpass.

We have made a very modest beginning in Advanced Studies at Newman. This is our second year of an honors course in mathematics, which is an introduction to mathematical analysis, including the fundamentals of analytic geometry and of differential and integral calculus. The Advanced Studies program offers a real challenge to schools with superior students; it will also constitute a challenge for the engineering colleges to accept such students on an advanced basis and to accelerate the scientifically minded and really talented young scholars to the highest reaches they can attain.

SAVILLE TO RETIRE FROM NEW YORK UNIVERSITY

Thorndike Saville, Dean of the New York University College of Engineering for the last 20 years, has announced that he will retire with the start of the 1957 fall term. Under his direction, the College formed a Graduate Division and a Research Division, the latter with an annual budget of $2,866,000; Dean Saville's academic programs have brought to major status many fields of engineering. A member of ASEE since 1915, Dean Saville has served as a Member of Council, 1943–1946; 1953–1955; Vice President, 1948–49; and President, 1949–50. In 1954 he was the twenty-seventh recipient of the Lamme Medal. He also has been President of the Engineers' Joint Council and of the Engineers' Council for Professional Development, as well as a Director of the American Society of Civil Engineers.

OPPORTUNITIES FOR FACULTY STUDY IN ENGINEERING

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Few would argue with the notion that the most desirable environment for effective instruction and learning involves bringing together teachers who are up-to-the-minute experts in their fields and students who are eager to become as well informed as their teachers. The converse of this statement is equally true: That environment is not desirable where students feel that their teachers are inexpert and behind the times. What, then, is the most desirable environment for effective learning on the part of college teachers?

This question can be variously considered. Most important perhaps is the acceptance of the principle by the institution where the individual is teaching that no teacher can continue to develop as he should if he is overburdened with teaching and committee assignments. Moreover, the institution should adopt an active rather than a passive role in creating the right kind of environment for additional learning on the part of its faculty. This implies that the institution give moral and, to the limit of its ability, financial encouragement to faculty study.

Sabbatical Policies Weak

Sabbatical leave policies in our colleges and universities leave much to be desired. An impression is abroad that fewer rather than more individuals are being given sabbaticals. The common practice of offering an eligible staff member a full year's leave at half pay or a half year's leave at full pay—salaries being what they are—often causes faculty members to decide that they cannot afford to make the financial sacrifice entailed in accepting sabbatical leave. This is a difficult problem for the institutions, for generally they must make every dollar do the work of two. Nevertheless, every effort should be made by Deans and Presidents to see to it that faculty members are encouraged to become more competent in every way and to the fullest extent possible.

From a somewhat different view point, the entire society must come to realize that the teaching profession is not a sinecure for lazy do-nothings. An attitude all too frequently encountered among the lay public is that the present salary level for teachers is quite adequate because, after all, they only work a few hours a week. Teachers are in an unfortunate position because of this attitude, since efforts to correct it could easily be construed as a drive toward securing special privileges and special consideration for a limited group. Nevertheless, there almost surely are ways to inform the public concerning the dire need for continuing, intensive study by teachers as a part of the job for which they are paid.

All concerned with maintaining and improving the quality of education in our colleges and universities must take it upon themselves to improve the environment surrounding the problem of providing opportunities for faculty study. Most colleges and universities already feel they have a very important responsibility here, but the responsibility of industry and government must also be recognized and accepted. Industry and government at all levels must accept a fuller share of the task of providing new and valuable experiences for college teachers.

Programs Open for Advanced Study

The environment in many of our institutions is even now highly conducive to the encouragement of self-improvement by faculty members. A considerable number of forward-looking industries have already initiated programs which can be significant in improving the competence of engineering teachers. Quite a few major laboratories operated by or for the government undertake important programs designed to provide research experience and on-the-job training for engineers and scientists. So far as I know, no directory has been prepared which lists opportunities of this kind. I therefore describe below some programs which have come to my attention. None is concerned with engineering alone, but all those mentioned do provide at least a limited amount of support in the field of engineering.

The word "study" in the context "Opportunities for Faculty Study" is meant to cover the broad field of faculty improvement. The following data therefore divide into two subareas: opportunities for formal study or training, commonly in an academic or quasi-academic situation; and opportunities for on-the-job work experience, usually involving research or development.

Formal Study

Formal training opportunities are generally associated with seeking an academic diploma. For college faculty, this would normally mean training leading to a master's or doctoral degree. In engineering, perhaps more than in most other disciplines, colleges have often found it desirable or necessary to use as staff members individuals trained to the first or second professional degree level only. Until relatively recent years, the proportion of engineers trained to the doctoral level in engineering has been quite small. The tremendous developments in science and engineering over the last few decades, however, have led to a need for more extensive training of those who teach the oncoming generation of scientists and engineers. Faculty members of engineering colleges who wish to obtain additional graduate training will find that there are several alternatives among which to choose. Teaching and research assistantships are relatively plentiful these days, and many universities would be delighted to obtain an experienced engineering teacher for such positions.

Obviously, the engineering teacher who has had, say, five to ten years teaching experience and has by the nature of things acquired responsibilities and tastes which cannot be supported at the relatively low levels of salary provided by such positions, generally finds them unacceptable as avenues to forwarding his formal training. Most predoctoral fellow-

ship programs provide stipends for graduate students which are purposely set low to conform with the level of support provided for the teaching and research assistants in our graduate schools. Thus these awards, too, generally prove inadequate for the established engineering teacher.

For the teacher with a doctoral degree, the situation is somewhat better. Several channels are open which provide more realistic financial support for established faculty members. The National Science Foundation has for five years awarded postdoctoral fellowships which carry stipends of $3400 plus dependency allowances of $350 per dependent. These awards also provide payment of required tuition and fees and travel to the institution where the Fellow is to study. Beginning with its March, 1957, awards, however, the Foundation has increased its postdoctoral stipends to $3800.

New Senior Awards

Last year (March, 1956) the Foundation announced the first group of awardees under its new Senior Postdoctoral Fellowship Program. These awards are available to individuals five years or more past the doctoral degree who wish to spend three to twenty-four months in additional training. Engineers are eligible to compete, and stipends are closely geared to the salary of the applicant as of the time he applies. Of the first 65 awards made under this new program, two went to engineers, though there were only *seven* applications classified under "engineering." There are indications—and hopes—that larger numbers of engineering faculty members will apply in years to come. These awards are made twice yearly, in March and October; information concerning the program can be obtained from NSF at all times.

Other groups make available limited numbers of awards for which engineers are eligible to apply, as, for example, the program now being conducted by the Southern Fellowships Fund, an agency of the Council of Southern Universities, Inc. The primary purpose of this program is the advancement of teaching and scholarship in colleges and universities in the Southern area.

A few fellowship awards are also made each year in the field of engineering by the John Simon Guggenheim Foundation, and these carry varying stipends determined on the basis of the specific financial needs of the individual receiving an award. Competition is very keen, but the honor associated with receiving a Guggenheim fellowship is correspondingly great. Although they are not fellowships, in the strict sense of the word, Fulbright Awards offer faculty personnel unusual and highly desirable opportunities for overseas study, research, and travel.

The addresses of the groups already mentioned, and those of two other fellowship-awarding groups (the John Hay Whitney Foundation and the American Association of University Women) are available from the author.

In recognition of the problems which exist for the established teacher when he wishes to obtain additional formal training, the National Science Foundation has devised a new fellowship program which is known as the NSF Science Faculty Fellowship Program. In general, its characteristics are as follows: Individuals who

have had three or more years experience as college teachers of science or engineering will be eligible to apply; the program will be open both to those who have and those who do not have a doctoral degree; stipends for these fellowships will be individually determined and will be based on the salary level of the applicant at the time he makes application; a major consideration in selecting Fellows for awards in this program will be the degree to which they show promise of becoming effective and inspiring teachers; although research may be undertaken during the tenure of one of these awards, the major purpose underlying the program is to improve the fellowship recipients as teachers rather than improving them as research workers.

On-the-Job Opportunities

Turning now to kinds of opportunities available in government and industrial laboratories, I have not been able to collate information concerning industrial laboratories and plants which offer summer employment—with its concurrent training elements—to faculty members. The number of such organizations is large and growing. Information is available, however, concerning opportunities in government laboratories and in laboratories supported in large measure by the Federal government.

First of all, the Oak Ridge Institute of Nuclear Studies has for some time been inviting faculty members from schools all over the country to come to Oak Ridge for varying periods of research and study. The project is known as the Oak Ridge Research Participation Program. Engineers and scientists selected are put on salary for the period during which they work at Oak Ridge—a salary commensurate with that paid by their home institution. Special efforts are made for participants to receive experience—usually in one of the divisions of the Oak Ridge National Laboratory—most valuable for them upon their return to their home institutions. Although the program is primarily research-oriented, with the expectation that participants will continue research after they leave Oak Ridge, it is hoped that the teachers involved in it will take back with them to their own campuses a refreshed and more inspiring point of view so that their instruction will become more vital.

The Brookhaven National Laboratory, operated by Associated Universities, Inc. for the Atomic Energy Commission, supports a program of this same nature. Several engineering faculty members can be taken care of at Brookhaven in essentially the same manner as that outlined for Oak Ridge. Engineers interested in design and construction problems associated with large particle accelerators—as well as those interested in nuclear technology—are particularly likely to find the opportunities at Brookhaven challenging. The Argonne National Laboratory, operated for AEC by the University of Chicago, offers similar opportunities.

Various other laboratories operated by or for the government welcome faculty members as temporary employees. One of the more notable examples is the Naval Research Laboratory in Washington, D. C. NRL can provide work-study opportunities for a good many faculty members for either the summer months only or a full academic year. Excepted civil service appointments are available

for such people at salaries ranging from about $6,000 to $10,000.

Other Naval laboratories provide similar opportunities for faculty members. The Naval Ordnance Laboratory, the Naval Air Station, the David Taylor Model Basin, the Naval Electronics Laboratory, and the Naval Ordnance Test Station all offer positions to visiting professors and staff members from universities and colleges.

A number of Air Force installations offer comparable work-study opportunities, as do several Army laboratories and units. A partial listing of these groups is available from the author, and if interest justifies can be printed in the JOURNAL.

The National Bureau of Standards on occasion finds it desirable to hire faculty personnel on a temporary basis. In addition, NBS will be glad to consider providing special research facilities for "visiting firemen" with special problems to investigate, who find it impossible to secure adequate facilities in their own institutions. In these cases, the visitors are treated as honored guests, but receive no remuneration from the Bureau.

Research Associateships

Other non-military governmental groups recruit small numbers of faculty members for summer employment of various kinds—the Bureau of Mines, the Coast and Geodetic Survey, the Department of Agriculture, and the Patent Office are examples.

Several laboratories mentioned have established another mechanism of possible interest to some faculty members. The Brookhaven National Laboratory, the National Bureau of Standards, the Naval Research Laboratory, and the Argonne National Laboratory all provide special research associateships for individuals who hold the doctoral degree and who wish to work with the respective staffs of these laboratories for a period of a year or so on research problems of mutual interest. These research associateships are set up so that they are similar in many ways to postdoctoral fellowships. They are limited, however, to the extent that the research carried out under these awards must be done at the specific laboratory involved.

For the benefit of Deans and Department Chairmen, it should be pointed out that most government laboratories offering research-training opportunities for faculty members are keenly conscious of the fact that they would be doing higher education—and science—a disservice if they attempted to recruit for their own staffs the people who come to them from college campuses for limited periods.

Clearly it is not possible to guarantee that every faculty member who leaves a college to take part in such programs will return to teaching. Equally clearly, some flow from universities to government laboratories cannot be prevented, even in the absence of the programs I have mentioned. In fact, a fairly strong case can be made for the desirability of such shifts of personnel—particularly if the direction of flow can be reversed occasionally, as it is.

Another category of opportunities for faculty members should be mentioned. In referring earlier to faculty opportunities at the Argonne National Laboratory, I omitted specific reference to the summer institute held there this past summer for engineers interested in learning more about the

impact of nuclear technology on various areas of engineering.

Co-sponsored by ASEE, AEC, and NSF, with administration by Northwestern University, this institute was based at and utilized facilities of the international atomic energy school at Argonne. A special series of courses was offered, tailored to needs of faculty members from American colleges of engineering. It is hoped that, by means of this special institute, engineering schools throughout the country will be enabled to inaugurate sooner than they otherwise might special courses for engineers interested in the new area which, for lack of a better name, is being called nuclear engineering.

Participants in this institute received stipends from two sources: their own institutions and a fund provided for this purpose by the National Science Foundation. A similar program was also carried out at the Brookhaven National Laboratory.

No one expects that eight-week sessions can transform mechanical and electrical and chemical engineers into nuclear engineers; but faculty members already trained in engineering may at such institutes determine, under unusually fortunate circumstances, ways in which special problems arising in this new and important area of nuclear energy utilization impinge on their own disciplines.

Several comparable institutes are planned for the summer of 1957. Information concerning these programs may be obtained from the Atomic Energy Commission (Civilian Reactor Division), Washington 25, D. C.

Mention should be made, as well, of the Radioisotope-Training Program conducted since 1948 by the Special Training Division of the Oak Ridge Institute of Nuclear Studies. About six times each year this program makes available four-week courses in the basic techniques of using radioisotopes. Participants attend at their own expense, but for those who need the subject matter covered, it is an extremely valuable offering.

The National Science Foundation has supported since the summer of 1952 a number of special summer institutes for college and high school teachers. These institutes, although differing in a number of respects from the Argonne Institute described above, also share some of its major characteristics. Last summer 25 such institutes were sponsored by the Foundation. This program is being expanded for the future, and it is quite possible that one or more such institutes directed specifically toward the further training of engineering college faculty members may be available during the summer of 1958 or thereafter.

Omitted from this quick survey is reference to opportunities of interuniversity exchange of personnel, such as the possibility of a faculty member at one institution becoming a temporary staff member at another—either as a research associate, a member of the instructional staff, or both. These possibilities are undoubtedly well-known to college and university faculty personnel—and since such opportunities are not operated on a programmatic basis, it is impossible to do more than note that those who are interested in exploring such possibilities can best do so through contacts in the academic community.

Other Possibilities

A survey of this type can never be complete—too many programs are dy-

ing, being born or modified all along. While the information presented above is considered to be fairly accurate, and a few of the possibilities mentioned are perhaps assembled here for the first time, the opportunities dealt with are certainly not the only ones that an interested faculty member could uncover if he wished to explore the subject more fully.

(The author has compiled a list of organizations from which further information can be obtained; this list is available on request.)

REPORT ON FEDERAL RESEARCH BUDGET

The National Science Foundation has released a new report, *Federal Funds for Science, V,* by C. E. Sunderlin, Deputy Director of the NSF. The report analyzes for the fiscal years 1955, 1956, and 1957 the federal scientific research and development budgets according to administrative agencies, scientific fields, and character of the project.

In fiscal 1956, the federal government spent an estimated $2.4 billion for scientific research and development activities, a 7% increase over 1955. For the current fiscal year, about $2.7 billion will be spent, 12% more than in 1956.

By far the greater part of the federal research budget is devoted to applied research and development. Although comparatively small, the proportion spent for basic research is increasing, and in fiscal 1957, basic investigations will account for almost 9% of the research budget. Physical sciences, including engineering, account for some 87% of the funds, the life sciences for 11%, and the social sciences for 2%.

TRENDS IN LABORATORY INSTRUCTION FOR MECHANICAL ENGINEERING

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A paper prepared for the Mechanical Engineering Conference, Ames, Iowa, June 26, 1956. Recommended for publication by the Division. The cooperation of twelve department heads and faculty members who returned questionnaires and helpful comments is appreciated.

The material which follows relates primarily to the senior laboratory courses offered in most Mechanical Engineering curricula as an important part of the instructional program. These courses are variously designated as Mechanical Engineering Laboratory or Heat Power Laboratory, and require from three to eight semester credit hours of instruction.

The primary purpose of these courses is to reinforce the teaching of scientific and engineering principles given in lecture courses. There seems to be general agreement that laboratory instruction is essential to successful mastery of the subject matter.

Laboratory Objectives

Secondary objectives of laboratory instruction differ among the several schools but generally include one or more of the following:

1. to teach the use of basic instruments to obtain accurate data
2. to teach the organization of tests
3. to teach the techniques of analyzing experimental data
4. to give practice in the communication of the results of experimental work, generally in the form of written or oral reports
5. to develop in the student the attitude of the research worker.

General acceptance of the above objectives as being important and desirable for senior students in mechanical engineering leads one to speculate on the possible applications of the techniques acquired. For background, therefore, it may be well to review the characteristics of a present-day engineering career.

Many definitions of engineering have been offered. The one I prefer is that given at the Seattle meeting in 1950 by Morrough P. O'Brien, namely:

"The activity characteristic of professional engineering is the design of structures, machines, circuits, or processes, or of combinations of these elements into systems or plants and the analysis and prediction of their performance and costs under specified working conditions. Professional engineers are persons qualified to engage in this activity."

This seems to distinguish the engineers as a group from the scientists through the emphasis on design and economics, with the addition that the mechanical engineer devotes his time primarily to design and analysis relating to machines and mechanical systems. The responsibility of the mechanical engineer to his employer or client requires that he be sure of

any recommendations he makes, and that he be convincing in presentation.

Normal procedures followed in the production of a new item begin with the conceiving of the device and a decision to produce it, based generally on a market survey. This is followed in turn by the preliminary design determining over-all characteristics, the development phase involving experimental investigation of new components, the production of a prototype or mock-up to verify the assembly as a whole, and the detailed design for production and final test of the product.

Young engineering graduates are generally involved in any of the experimental phases of the program, namely:

1. research activities which lead to the initial conception
2. developmental activities
3. testing of final product
4. acceptance tests by purchaser.

For all of these activities, the secondary objectives would seem to lay a suitable foundation and to emphasize the importance of acquisition of techniques in the laboratory.

Trends and Fashions

Having attempted to set down the present position of laboratory instruction, it is appropriate to consider trends, defined as underlying or prevailing tendencies and inclinations. These are predictable in some cases, and subject to fashion in others. For example, one can evaluate the trend of atmospheric temperature from scientific principles and the observation of factors such as the change in gaseous components. Similarly, the relationship between the removal of gas from wells in the Long Beach area and the subsidence of land on Terminal Island makes possible the evaluation of the trend of the latter quantity.

Fashions seem to rule, however, in many instances besides the familiar one of clothing. For example, the subjects offered by the departments of Mechanical Engineering over the years reflect the technically important devices of the time. Specifically, where does one find today a course on valve gears for steam engines? Thirty years ago one such course could be found in most departments.

Conversely, an examination of the catalogs of fifty years ago would reveal few, if any, courses in aerodynamics, a subject presently listed by many departments of Mechanical Engineering. Thus, it would appear that the scientific subject matter of laboratory courses will reflect the changing subject matter of the practicing mechanical engineer. This has included in past years equipment for central power stations, air conditioning devices, aeronautical engineering devices, and presently shows increasing emphasis on the gas turbine and other modern propulsion components as well as on the use of nuclear energy.

Trends influenced by the secondary objectives have to do with the techniques to be developed for later use. Whereas in years past it has seemed important for the young man to operate machinery, to do a certain amount of service work on it, and to be a sort of combination millwright and supervisor, the modern emphasis seems to be on the analytical side.

Modern research or test groups generally include technologists who

understand the functioning of equipment, and mathematicians or scientists who are qualified to do the detailed analytical work, as well as the engineering graduate who would normally be expected to perceive the relative importance of the various pieces of work to be done and to organize the group for most effective completion of these activities. One function of the senior laboratory course should be to develop the frame of mind and the techniques which should enable the graduate to play his proper role.

Student Needs and Interests

Before terminating this general theme, some attention should be given to the needs and interests of those primarily concerned with this course. The students below the senior year look forward to the taking of a difficult and time-consuming course. Graduates of the curriculum with a few years of experience in industry look back on the course with nostalgic memories, and frequently state that the habits of careful investigation and analytical evaluation formed there have been most valuable to them.

On the other hand, chairmen of departments of Mechanical Engineering generally have serious problems in the staffing of these courses. The young faculty member generally can expect at least part of his teaching assignment to consist of this laboratory course. For each of these interested parties, one could invent a trend favorable to his needs or desires.

For the undergraduate, a desirable trend would probably indicate more actual laboratory work and less report-writing and evaluation. For the young man a few years out of school, it would probably be quite the opposite. For the departmental chairman, a favorable trend might be one toward reduction or even elimination of laboratory courses and the headaches that go with maintenance of the facilities and staffing problems.

For the young engineering teacher, a favorable trend might involve better preparation of the students through more laboratory work in previous years and an increased ability on the part of the student to express himself. No doubt each member of the audience who has been involved in the course will have invented for himself a favorite trend which the course should take. To a certain extent, the trend in any institution will be influenced by the above factors.

Conclusions

In summary, it would appear that the future development of the senior laboratory courses for mechanical engineering students will be influenced as to subject matter by the changing emphasis of the profession. The particular techniques to be developed in the student seem to be moving more toward report-writing and evaluation rather than toward operational and manipulative skills.

AN UNDERGRADUATE EXPERIMENT IN SIMILITUDE

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A paper presented at the evening conference of the Mechanical Engineering Division, June 26, 1956, Ames, Iowa. Recommended for publication by the Division.

Engineering consists very largely of perceiving useful similarities in the behaviors of elementary bits of engineering substances, of macroscopic machine elements and processes, and of entire machines and systems. Consequently, it becomes most important to stimulate an undergraduate awareness of these similarities and of their significance.

Unfortunately, similitude is a tremendous field which should be surveyed from many points of view. This paper suggests a series of three laboratory experiments which will demonstrate a particular kind of similitude and present an opportunity to verify a prediction of machine characteristics, based on similitude considerations, but which would not be anticipated intuitively.

The concept of similitude and the application of its principles are topics well suited to laboratory exposition. On the one hand, they are directly related to the practice of experimental engineering; on the other, their consequences, which often contradict intuition, require confidence-inspiring physical demonstration. In the hands of an engineer who comprehends it intellectually, has confidence in its universality, and has experienced its utility, similitude is an enormously powerful tool. Comprehension may perhaps be achieved in the lecture hall, but laboratory experience is the only hope of inspiring confidence and of demonstrating utility.

Focus on Fluid-Dynamic Similitude

Since the similitude concept is of special value in dealing with fluid-dynamic machines, it is this aspect of the subject which these experiments emphasize. The scope is arbitrarily restricted still further to incompressible steady-flow phenomena. The purpose of the experiment is to demonstrate usefulness in a simple view of fluid-dynamic phenomena in practical machines, to wit:

(1) Similitude between two fluid dynamic events means detailed kinematic similitude, i.e., geometric similarity of streamlines. (Note that this similarity requires geometric similarity of apparatus, and equality of all ratios for corresponding velocities.)

(2) Laminar boundary layers are of negligible dimensions in relation to the flow passage sizes, and outside these layers both normal and shear stresses in the fluid depend exclusively on inertial effects.

(3) As a consequence of (1) and (2) and the assumption of incom-

pressibility, the pressure differences between corresponding points under similar conditions are proportional to the fluid densities and to the squares of *any* corresponding characteristic velocities.

(4) Most important of all, the detailed kinematic similitude of (1) is a necessary consequence of *gross kinematic similitude*. The latter is established when all *external* controls have been used to effect kinematic similitude. Thus two velocities characterizing the kinematics of a pump are susceptible to independent external control. One of these, associated with the moving parts (say the peripheral speed of the impeller), is regulated by adjusting the shaft speed.

The second, associated with the fluid flow (say the mean velocity in the inlet pipe), is regulated by adjusting the flow resistance in the external hydraulic circuit. A particular ratio between these two controllable velocities, wherever established for a particular machine or its geometrically similar counterparts, corresponds to a particular detailed kinematic pattern and to a corresponding dimensionless dynamic performance. This is the essential idea underlying the whole group of experiments.

The student should embark on these experiments only after having been intellectually committed to this principle and to its corollary. The principle is summarized for a pump or hydraulic turbine:

$$\frac{p_i - p_j}{\rho V_c^2/2g_c} = f\left(\frac{V_c}{\omega D}\right) \qquad (1)$$

and the corollary is

$$\eta = F\left(\frac{V_c}{\omega D}\right) \qquad (2)$$

where

D—Any characteristic dimension—say impeller diameter
g_c—Proportionality constant in Newton's second law
p_i, p_j—Pressures at any two points i and j, all i's and all j's having corresponding locations
V_c—Any characteristic *fluid* velocity—often chosen to be Q/D^2 where Q is volume flow rate
ρ—Density of fluid
ω—Angular velocity of shaft
η—Efficiency.

Presumably the relationships (1) and (2), or their equivalents, will have been developed in Fluid Mechanics courses, either by direct physical reasoning about incompressible fluids of nearly zero viscosity or through the application of dimensional analysis. In neither case will the student be really convinced of the existence or significance of these relationships.

The physical reasoning is apt to seem abstract, and the dimensional reasoning leads to these simple conclusions only after the teacher has exercised his judgment in pronouncing unimportant the Reynolds, Froude, Peclet, and other numbers involved. Despite his skepticism or apathy, the student should be made conscious that these experiments are centered on equations (1) and (2).

Incidentally, I will apologize now for my cavalier treatment of Reynolds, Mach, or any other of your favorite similarity indices. The emphasis is placed upon the kinematic index because of the dominance of its role as compared to those usual for viscosity, surface tension, and even for compressibility.

The Experimental Vehicle

It is the purpose of these experiments to produce experiences which are advantageously correlated on a dimensionless basis—thereby demonstrating the similarity of apparently diverse events and implying similarity of a great many events not observed—and to pose some engineering questions which the similitude principles will answer. A fluid torque-converter, in its components and in its entirety, exhibits very interesting dynamic performance characteristics. Unfortunately in its commercial form it is a little too compact for investigation in an educational laboratory.

A pair of centrifugal pumps (one being run backward as a turbine) can, however, compose a torque conversion system which is readily explorable in some detail. The accompanying sketch indicates such a pair of machines equipped with dynamometers as they are arranged in our laboratory at M.I.T. Not only can these machines be operated jointly as a converter, but they can be tested separately as pump and turbine.

First Experiment—Overall Performance

This experiment is made without reference to similitude concepts; it is intended that in retrospect it will constitute an object lesson in the economy of similarity correlations. The operating variables pertinent to the complete torque converter are identified: N_P and N_T, the input (pump) and output (turbine) shaft speeds, are independently controllable, and P_P and P_T are the dependent input and output powers. The ratio of the latter, P_T/P_P, is the converter efficiency, η. The performance of the converter is, then, fully described by the relationships,

$$P_T = F(N_P, N_T), \tag{3}$$

$$\eta = f(N_P, N_T). \tag{4}$$

The experiment proper consists of establishing these relationships by conventional test procedures. During the course of this test the geometry of the converter should remain fixed, i.e., the valves should direct all the pump flow through the turbine, and restrictions between the machines and in their connections to the common sump should be minimized.

Second Experiment—Component Tests

This experiment is intended to establish the basis for "explaining" the converter performance as established by the first test series. A very modest definition of "explanation" is adopted, namely, demonstration of the consistency of that performance with the behaviors of the pump and turbine considered separately. Specifically, the experiment consists of determining these individual operating characteristics for both machines.

From the educational point of view, student participation in the planning of this experiment, with its ultimate objective in mind, is crucial. Each of the planning steps enumerated below should be taken with the greatest of care; none should be glossed over as obvious, and no data should be taken without specific understanding as to how they will be used to achieve the ultimate goal.

(1) The components must be identified and their boundaries defined.

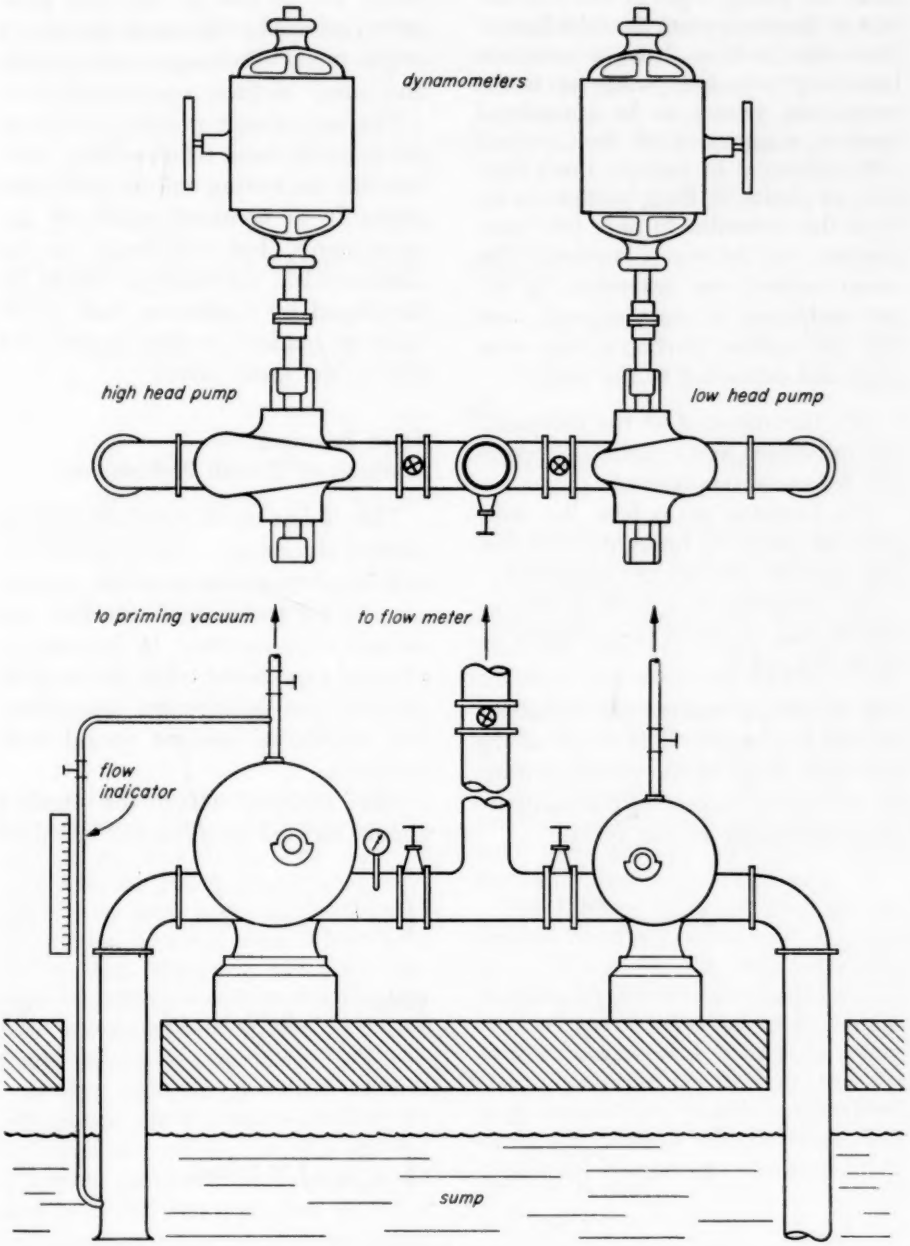

FIGURE 1. *Plan and elevation sketches of pump-turbine system for similitude experiments.*

Does the pump begin at the free surface of the sump or at the inlet flange? Does the turbine have a common boundary with the pump, or is the connecting piping to be considered another component of the system? (My advice is to exercise one's freedom of choice in these matters to reduce the converter to only two components, (a) the pump, starting at the sump surface and extending to the pressure gage at its discharge, and (b) the turbine, starting at this same gage and extending to the sump.)

(2) Identification of the independent and dependent variables of operation for each component.

(3) Decision as to how the independents are to be brought under control and the dependents measured.

(4) Adoption of a mode of correlation for the results in view of their intended purpose.

The similitude concept enters the picture at this point. The result of the last three steps of the planning process should be to predict the existence of relationships in the forms:

where p_P, p_T and p_0 are total pressures (referred to the same elevation) at the pump discharge, turbine inlet, and sump surface, respectively.

The experiment proper consists in determining these relationships. Presumably the testing will be performed primarily at constant speeds of the components, but confidence in the dimensionless correlations should be developed by confirming that points taken at random at other speeds will fall on the same curves.

Third Experiment— Synthesis of Overall Performance

This is less an experiment than an analytical exercise which should result in a demonstration of the consistency of the results from the first and second experiments. It becomes a physical experiment when the analysis develops an unexpected generalization which the student should wish to check.

The analysis which the student should attempt by himself is based on

$$\psi_P \equiv \frac{p_P - p_0}{\rho/g_c \times N_P^2 D_P^2} = f_P\left(\frac{Q_P}{N_P D_P^3}\right) \equiv f_P(\phi_P), \tag{5}$$

$$\eta_P \equiv \frac{Q_P(p_P - p_0)}{P_P} = \frac{\psi_P \phi_P}{\dfrac{P_P}{\rho/g_c} N_P^3 D_P^5} = F_P(\phi_P), \tag{6}$$

and

$$\psi_T \equiv \frac{p_T - p_0}{\rho/g_c \times N_T^2 D_T^2} = f_T\left(\frac{Q_T}{N_T D_T^3}\right) \equiv f_T(\phi_T), \tag{7}$$

$$\eta_T \equiv \frac{P_T}{Q_T(p_T - p_0)} = \frac{\dfrac{P_T}{\rho/g_c} N_T^3 D_T^5}{\psi_T \phi_T} = F_T(\phi_T), \tag{8}$$

the recognition that *when* the pump and turbine are coupled as a torque converter

$$p_P - p_0 = p_T - p_0 \tag{9}$$

and

$$Q_P = Q_T. \tag{10}$$

These facts lead to the further equalities

$$\psi_P \frac{\rho}{g_c} N_P^2 D_P^2 = \psi_T \frac{\rho}{g_c} N_T^2 D_T^2 \tag{11}$$

and

$$\phi_P N_P D_P^3 = \phi_T N_T D_T^3. \tag{12}$$

These latter equations may be reformulated thus,

$$\psi_T = \psi_P \left(\frac{N_P}{N_T}\right)^2 \left(\frac{D_P}{D_T}\right)^2 \tag{13}$$

and

$$\phi_T = \phi_P \left(\frac{N_P}{N_T}\right) \left(\frac{D_P}{D_T}\right)^3. \tag{14}$$

Now because the diameter ratio is known, if we choose an arbitrary operating point Ψ_P, Φ_P (any pair of values on the pump operating curve), Ψ_T and Φ_T each become functions of N_P/N_T and hence of each other. This intersection represents the only possible operating condition for the turbine corresponding to the assumed pump operating condition.

Among other things which are thus established are the corresponding efficiencies η_P and η_T. In view of the efficiency definitions in equations (6) and (8), and the equalities of flows and pressure differences in equations (9) and (10), we also know the converter efficiency,

$$\eta = \eta_T \eta_P. \tag{15}$$

Repetition of this procedure results in the establishment of an operating curve for the converter. This information can be expressed in various forms, among which are the following:

$$\eta = f\left(\frac{N_P}{N_T}\right) \tag{16}$$

and

$$\eta_T = \frac{Q(p_T - p_0)}{\rho/g_c \times N_T^2 D_T^5} = F\left(\frac{N_P}{N_T}\right) \tag{17}$$

or

$$\frac{P_T}{\rho/g_c \times N_T^3 D_T^5} = F\left(\frac{N_P}{N_T}\right). \tag{18}$$

The relations (16) and (18) are precisely equivalent to functions (3) and (4) as determined in the first experiment; this equivalence is a main point of the final test. The simplicity of the efficiency function (16) is probably not expected by the student. Its validity should be verified by random spot checking of the overall performance. It should also be pointed out that its existence might have been directly anticipated from the basic similitude concepts.

The ratio of shaft speeds *is* the index of kinematic similitude, because these speeds are the only externally controllable kinematic quantities (remember we're not allowed to manipulate valves because they vary geometry), consequently they control the gross kinematics, hence the detailed kinematic pattern of the fluid flow within the component machines.

In Closing

This paper has been intended less as a prescription for a specific series of experiments than as an exposition of an important engineering concept

which is peculiarly suited to laboratory treatment. If one exhausts the possibilities of the torque converter—including such problems as choosing a more appropriately sized turbine for use with a given pump, or selection of the best diameters for a given power and speed of input—he can always turn his attention to the deep-well jet-pump, an even more challenging synthesis of fluid dynamic components, for study.

SUMMER COURSES IN AUTOMATIC CONTROL

The University of Michigan College of Engineering has announced two summer Intensive Courses in Automatic Control. The first is scheduled for June 17 to 22, and the second for June 24 to 26, 1957. The aim of the courses is to teach engineers the fundamentals of modern automatic control and to provide a comprehensive set of notes to serve as a framework for further study.

Course I will consist of the fundamentals in measurement, communication, and control and will include some basic work in nonlinear systems. Course II will take up applications of the fundamentals to more advanced problems. There will be four hours of lecture each morning and three hours of laboratory demonstration in the afternoon. Extensive use will be made of computing, instrumentation, and servo laboratories. The role of analog computing methods will be emphasized.

April 15 is the closing date for registration. Further information can be obtained from Professor L. L. Rauch, Room 1521, East Engineering Building, University of Michigan, Ann Arbor, Michigan.

ELECTRICAL THEORY FOR NON-ELECTRICAL STUDENTS

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A paper presented at the Electrical Engineering Conference, June 26, 1956, Ames, Iowa. Recommended for publication by the Division.

In what follows, we have tried again to find answers to the following long-lived questions:

(1) What electrical engineering topics should be included in the curriculum for non-electrical engineering students?

(2) Should all non-electrical engineering students take the same electrical engineering courses?

(3) How much time is required to present electrical engineering topics to non-electrical students?

These questions are not new and answers have been given before. It is desirable, however, that we continue to evaluate our curricula, especially in service areas.

Curricular Planning

In formulating a curriculum, a sound beginning is to determine the objectives of the curriculum and the limits within which we must work. The faculty of the engineering schools at the University of Pennsylvania some time ago approved the following "Principles for the Construction of Engineering Curricula."

1. There is an optimum "work week," of class hours plus study for the average student, a load which totals approximately 50 hours.

2. All engineering students are likely to be best prepared to learn about the (presently unknown) living they will do after graduation if they undertake one of the several balanced and coordinated undergraduate programs of mathematics, physics, and chemistry; oral and written communication, humanities, and social studies; engineering science; and work in their major field.

3. The effectiveness of any undergraduate program can be enhanced by:

   a. Maintaining standards of admission that will result in continual improvement in the quality of our programs and the quality of our graduates.
   b. Continually developing an advising system that leads to the optimum stimulation of each student to do the best job he is capable of doing.
   c. Establishing means for continually keeping the student aware of the interrelation of the various components in his broad program of education.

4. The major purpose of each course in the curriculum is to lead the student to understanding, enthusiasm, and respect for methods

and concepts in the scholarly discipline of which the course is one part. This is best accomplished by the rigorous analysis, in depth, of selected topics, and not by the presentation of encyclopaedic facts or the superficial survey of many topics.

a. If each course is limited to a few topics, the coordination of courses is imperative.

5. Except for a few courses of the "engineering major" group, presentation should not be exclusively for engineering students.

a. The courses in engineering science should be, as the name implies, basic discussions using mathematics, physics, and chemistry. They should be so conceived that physicists, chemists, and mathematicians will wish to take them as part of a major program.

6. In the area of social studies and humanities, preference should be given to courses that emphasize fundamental concepts rather than specialized techniques.

7. Some all-pervading and intrinsically important aspects of the engineering profession, such as human relations, concise and effective speech or writing, safety, and costs of design or production should be emphasized in every course whenever appropriate.

8. It is wise to design each engineering curriculum so that those who wish to go on to graduate study and research are well equipped to do so, but care should be taken to design the undergraduate curriculum so that it does not include topics that properly should be the subject of graduate study.

9. Each curriculum should be designed so that, by elective or other procedures, the best students can take a challenging sequence of work that will bring forth their best efforts.

10. In designing a curriculum, every effort should be made to maximize the efficiency with which a potentially good engineer completes his undergraduate training. Thus, for example, the prerequisite system and scheduling of courses should be planned, if possible, so that an occasional failure in one course will not result in excessive loss of time, and so that it will be feasible to encourage and admit students with partial training in other disciplines (such as liberal arts) into engineering programs on an advanced standing basis with a minimum loss of time.

11. It is fundamental to the principles listed herein that engineers of the future must be trained broadly and basically. As undergraduates, they must first find out how to learn. Engineering curricula should, therefore, develop in the direction of unity of purpose and method.

Alumni and Faculty Agree

This set of principles is generally compatible with the ASEE Report on the Evaluation of Engineering Education. Also, the results of a questionnaire sent to alumni of The Moore School of Electrical Engineering, University of Pennsylvania, several years ago indicate that these principles meet with alumni approval. The questionnaire was designed to obtain from each alumnus a critical evaluation of the strengths and weaknesses in his undergraduate education. An example of the agreement between our

faculty at Pennsylvania and our alumni is found in the reply to this question:

"Should the curriculum emphasize: (a) basic physical concepts and their theoretical elaboration in some typical fields of application, or (b) more detailed discussion of current engineering practice?"

The very large majority of those replying favored emphasizing basic physical concepts rather than current practice. It was frequently suggested that current engineering practice should serve primarily to illustrate how basic concepts are applied. Only for the classes graduating during the depression years of 1931–1935 did a majority favor emphasizing current engineering practice.

In spite of the many people who have in recent years indicated the need for emphasizing the fundamental concepts, it cannot be assumed that this is a universal opinion. There are many who feel that the emphasis should be on the practical. It is argued that for the superior student who will take graduate work, the emphasis on basic concepts is fine, but that the average student is not well served by such a course.

The need for practical knowledge seems to be most keenly felt by the civil engineers. Most of the employers of civil engineers do not have training programs, and the new employee is expected to take a transit and lay a track or calculate beam stresses for a bridge as his first assignment. Perhaps we should not discount the student's first day on the job, but it is important to remember that he may expect to be on the job for 40 years after graduation.

What EE Topics for Non-Electricals?

With the student's needs and a set of principles as a guide, what topics should be included in the curriculum for non-electrical students?

It can be argued that the topics that are included in any course are of no importance. It is only necessary to develop the originality and creativity of the student and to inspire and motivate him to learn. The topics that are treated need not be related to any specific needs of the student following graduation.

This argument is, to a considerable degree, valid. It is, however, probably easier to motivate the student if the topics discussed are relevant in time and circumstances. Basic physical concepts can be appropriately illustrated with examples from current practice. All things being equal, the more current the illustration, the better the student motivation.

Suppose we divide into five areas the topics that might be included:

(1) Electric circuits—This would include the steady-state and transient response of linear circuits to a-c and d-c driving functions.

(2) Electronics—including physical electronics and electronic circuits.

(3) Fields—including static-electric and magnetic fields, and electromagnetic fields.

(4) Energy conversion—including static and dynamic conversion devices.

(5) Control—including instrumentation, measurement and principles of control.

Our colleagues in all the engineering departments at Pennsylvania

would like their students to have some knowledge of electric circuits and electronics, and they would like some work directed toward instrumentation and control. Some believe that field theory is important, while others place rotating machinery high on the list.

We might hope that all engineers could be familar with each of these areas. It was suggested by several staff members that topics which are largely descriptive, such as the operation of rotating machines, could be assigned to the student for outside reading. Other topics of importance, such as field theory, which cannot be treated adequately due to lack of time, might also be assigned as outside reading.

Such a procedure, however, would appear to contradict the principles stated earlier. In the limited time available, it is perhaps a more sound procedure to treat just one or two of the five areas. To treat all five would require superficial coverage, and maximum motivation cannot be achieved with such a survey course. In addition, the student probably learns and retains more when exposed to an intensive treatment of a few topics rather than cursory treatment of many.

It appears desirable, then, to select specific material from the electrical engineering curriculum for presentation to non-electrical engineering students.

There are a number of reasons why circuit theory is a good first course. It deals with basic physical principles such as conservation of energy, conservation of electric charge, and superposition in linear systems. It makes use of the mathematical background the student has obtained in calculus and differential equations. The problems treated in a circuit theory course are analogous to those in other areas of considerable interest to various student groups.

First Selection—Circuits

For example, civil engineers have pipe network problems which can be solved by using the electrical analogy. For the mechanical engineer, lumped-constant mechanical systems can be considered as mechanical networks, and can be represented by an electrical analogue. Also, the fundamental concepts studied in the circuits course can be readily illustrated.

Because a circuits course is also the first course for our electrical engineering students, it might appear desirable to have the same course serve both groups. All engineering students at the University of Pennsylvania have the same background in mathematics and physics. It therefore appears feasible to present a common course to all students with this common background. In such a basic course there would perhaps be a greater compulsion to avoid an excess of current illustrations than there would be in one designed for a specialized group.

A common course has the disadvantage, however, that the most timely topics and illustrations for the electrical engineering students in the first of five terms of circuits courses are not necessarily the best topics for the non-electrical students in their first and perhaps last circuits course.

Another consideration is time. It is quite likely that the course for non-electricals will be one hour shorter than the corresponding course for electrical engineering students. It may be two hours per week instead of three, for example. Consequently

the two courses could not well be identical. Certain topics must be dropped, but the level of treatment would be the same for all students.

Electronics Second

For a second course, electronics has many advantages. It is attractive to the student and makes motivation less of a burden. It draws heavily upon the student's earlier work in circuits and physics. It deals with such fundamental concepts as the motion of electrons in an electrostatic field, the theory of emission, and the conservation of charge. It provides many interesting analogies. For example, the laws of motion of an electron in a uniform electrostatic field are the same as those of a body falling under the influence of gravity. Also, the student will discover that electrons can be reflected, refracted, and focused like light rays.

A good deal of flexibility is possible with this second course. Physical electronics and vacuum tube circuits can both be included, or circuits alone can be considered. Since the student has already had a course in the fundamentals of circuit theory, vacuum tube circuits are suitable for the second course. The starting point can be the equivalent circuits desired from the tube characteristics given, which are taken as experimental facts. The remainder of the course will then involve, essentially, an application of circuit theory concepts.

Whether physical electronics and vacuum tube circuits are both considered, or vacuum tube circuits only, the electronics course can still be on the same level as similar courses given to electrical engineering students. The only sacrifice would be in the breadth of topics covered, rather than in the treatment of these topics.

A bare minimum for both the circuits course and the electronics course is two hours per week. In addition it is almost essential to have a laboratory with the electronics course. The laboratory would require an additional three hours. Thus the minimum time spent by non-electrical students in electrical engineering courses would be seven semester hours total.

These figures correspond to the hours now taken by the chemical and metallurgical engineering students at the University of Pennsylvania. The mechanical and civil engineers take some additional hours. Any further time available can well be spent in a laboratory course added to the circuits course, or in dealing with concepts of energy conversion.

Like the other two, a course in energy conversion should stress fundamental concepts and draw on material from physics and circuits. It may be that no detailed machine analysis at all would be included. However, if the student has a basic knowledge of how and why electrical machines work, he may be better off in the long run than one who has been exposed to many sets of operating curves which have little meaning to him.

Conclusions

To summarize, then:

(1) What electrical engineering topics should be included in the curriculum for non-electricals?

Circuit theory and electronics appear to be good choices, the first course to be in circuit theory and the second in electronics. Both courses would be at the same level,

though probably not in as great detail as the corresponding courses given to electrical engineering students.

(2) Should all non-electrical engineering students take the same electrical engineering courses?

Circuit theory and electronics are the preferred areas for all the non-electricals, so that it is reasonable to have common courses for all these students. The time that is available for the several groups may not be the same, however, and this makes separate courses necessary. Also, with separate courses, the instructor can emphasize those items of greatest interest to a particular group.

(3) How much time is required to present electrical engineering topics to non-electrical students?

A minimum of seven semester hours is required. More is desirable, but if the student's work week is to be approximately 50 hours, it is not likely that the number of available semester-hours for these courses will greatly exceed seven.

Thus, all non-electrical engineering students would take basically the same electrical engineering courses, although they might not take them at the same time, and they might not all take the same number of courses, or be exposed to the same number of topics. The material they receive in class would not differ fundamentally, however, from the material presented to electrical engineering students. Such a unified approach seems at least to promise a favorable result in the long debated and difficult area of service courses.

INVENTORY OF INSTRUCTIONAL TELEVISION RESEARCH

The Educational Television and Radio Center recently published a comprehensive report containing findings of 71 research projects dealing with instructional television. Compiled by Hideya Kumata, "An Inventory of Instructional Television Research" contains abstracts of research projects, providing a resource document for educators and others interested in educational television. The 155-page book also contains a selected bibliography of 173 annotated items on TV as a teaching tool. Copies can be obtained from the Center, 1610 Washtenaw, Ann Arbor, Michigan, at a cost of $1.00 each.

AN ENGLISH PROFICIENCY TEST FOR ENGINEERING STUDENTS

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Presented at the Annual Meeting of the A.S.E.E., Joint Conference of Educational Methods and English Divisions, Iowa State College, June 25, 1956. Recommended for publication by the Educational Methods Division.

This paper describes tests employed at The Pennsylvania State University during the past ten years in the administration of a special graduation requirement in English for students enrolled in the College of Engineering and Architecture. These students are required to take an English Proficiency Test at the end of their junior year and those who fail this examination must schedule and pass an appriate non-credit remedial course in order to complete the requirements for their graduation.

The examination is intended to test the student's ability to organize thoughts logically and present them clearly and convincingly in accordance with current standards of formal English usage. In this test, the student must demonstrate this ability by writing a paper in response to an assigned problem which requires 1) the analysis and interpretation of certain information, and, 2) the presentation of this interpretation in a paper intended for a specified purpose.

Comprehensive Problems Used

The test is administered as a service to the College of Engineering and Architecture by the Department of English Composition in the College of Liberal Arts on the basis of policies formulated by Professor T. J. Gates, Head of that Department. Problems for these tests are developed by a joint committee of the two Colleges.

Many of these problems have required the interpretation of graphs or tabulations of data relating to the industrial development of the United States. A problem of this type is quite suitable for the purpose, regardless of differences in technical content of the various curricula, because all students concerned take a course in American Economic History during the junior year.

As a typical example, a recent test presented a problem relating to the increase in mechanical power in the United States and shifts in the labor force. One tabulation gave data showing the changes during the years 1870 to 1950 in the Population, Horsepower-Hours per Year from Mechanical Sources, and Annual Horsepower-Hours per Person. A second tabulation gave data for the same period showing changes in Population, Labor Force, and Distribution of Labor Force among Agriculture, Manufacturing, and Trade and Service. In a paper of approximately 500 words, the student was asked to explain these changes and discuss significant social and economic developments resulting from them.

A period of three hours is scheduled for the examination, and the paper is written without previous knowledge of the problem. Students are advised to devote about one hour to analysis of the data and development of inferences for discussion in the paper, and another hour to preparation and revision of a rough draft, before writing the finished paper submitted for scoring.

Scoring Carefully Planned

The papers are scored by a team of five men having the rank of Professor or Associate Professor in the Department of English Composition. Before beginning their work on the papers submitted in an examination, this group meets with the professor in charge of the project for review of the problem and discussion of details of interpretation which should be found in acceptable papers. This conference is considered to be one of the most important details in the administration of the test.

The scoring scale is also reviewed at this time, so that all papers can be scored on a common basis. This scale was developed by Professor J. S. Bowman of the Department of English Composition, who has been responsible for the administration of this test since it was established. Under this scale, the highest attainable score is 200 points, with *Interpretation* and *Organization* each carrying a maximum of 50 points, with a total of 100, while *Style and Mechanics of Writing* together carry a total of 100 points. The passing score is 115 points.

Detailed Treatment

The score on *Interpretation* is intended to evaluate the student's ability to analyze and interpret the data thoroughly and accurately. The scoring scale for this item includes a series of brief descriptive terms with an appropriate numerical range assigned to each.

The score on *Organization* is intended to evaluate the student's ability to organize his discussion clearly and logically for easy and meaningful reading. The scoring scale includes descriptive terms, with a numerical range for each, which apply to general organization and over-all grouping, paragraphing, and the use of clarifying devices such as introduction, transition, and summary.

The score on *Style and Mechanics of Writing* is intended to evaluate the student's ability in accordance with current standards of formal English usage. Separate scores are recorded for spelling, punctuation, vocabulary, and sentences. For each of these elements, there is a scoring scale which is applied by counting the number of errors found in the paper.

Initial scoring of the papers reveals a group with scores well above passing and another group with scores far below passing. These scores are considered final unless the scorer requests a check. All other papers are given a second reading, and no paper in this group is given a final score until at least two members of the scoring team have read the paper and agreement has been reached on the score to be reported. In many cases, there have been three readings before final decisions were made.

Members of the scoring team receive special compensation on an hourly basis for the time spent in conferences and in scoring papers. In view of the details of procedure just

described, it will be evident at once that the administration of this special graduation requirement is an expensive item. The cost is especially high owing to the assignment of high-ranking and thoroughly-qualified staff members to the scoring teams. The provision of appropriate remedial instruction for students who fail also adds to the cost.

Remedial Work Worth While

The non-credit remedial course for students who fail in this test demands work equivalent to that of a course carrying three semester credit-hours. The teachers in the remedial classes are chosen from members of the scoring team and the work is developed to meet individual needs in so far as is possible. The final examination is another English Proficiency Test similar in its general features to that which the student failed originally.

During the ten years that the test has been administered, the percentage of failures has varied from 17 to 36, with recent classes averaging 28 per cent. Each year, a few students fail in the remedial course and are required to repeat that work.

There appears to be no clearly defined relation between scores in this English test and other items in the academic records of the students. In general, as would be expected, students ranking high in their class have good scores in the test, while those ranking low in the class have poor scores. There are, however, many exceptions to this rule which appear to defy explanation.

It is evident that many failures result from basic deficiences in English which are not fully remedied by freshman work. All entering freshmen take an English Placement Test and those who fail are required to pass a non-credit remedial course before being permitted to enroll in the regular freshman courses in English. Of the students who failed in this Freshman Placement Test and later reached junior status in engineering, about 70 per cent failed in the Proficiency Test. Of those who passed the placement test, on the other hand, only about 25 per cent failed in the junior test.

In the freshman year, all students take a course in English Composition and Rhetoric and another in Exposition. About 45 per cent of those who failed the junior proficiency test had averages under C in these freshman courses, while 15 per cent of those who failed the junior test had averages in the freshman courses of high C and above.

Interpretation Difficult

Comparison on another basis shows that about 55 per cent of the students with averages below C in the freshman English courses later failed in the junior test. Only 16 per cent of those having an average of C failed in the junior test, only 8 per cent of those averaging B failed, and very few averaging A failed later tests.

Studies involving an analysis of scores in Interpretation, Organization, and Style and Mechanics of Writing, as separate parts of the total score, have revealed little real significance. In most cases of failure, there were low scores in all three parts. There have been, however, many failures which resulted chiefly from serious weakness in Interpretation or in Organization. Fewer failures have resulted from weakness only in Style and Mechanics of Writing.

The distribution of failures among curricula has not varied greatly from year to year. For example, the students in Architecture, who have relatively few courses requiring written reports, usually show a high percentage of failures. By comparison, the Civil Engineers, who consistently show the lowest percentage of failures, take a required course in Technical Report Writing in the junior year. It has been quite evident that, as would be expected, the percentage of failures among a group of students is closely related to the amount of formal written work required of them in the courses taken after the completion of the required freshman work in English.

To Summarize

The most important features of this English Proficiency Test are briefly described as follows:

The test is employed for the purpose of administering a special graduation requirement under which students must demonstrate ability to organize thoughts logically and present them clearly and convincingly in accordance with current standards of formal English usage. The test is so designed and administered that the student must actually demonstrate this ability by writing a paper, without previous preparation, in terms of an assigned problem. The papers are scored and the student's ability is evaluated by high-ranking members of the faculty in the English Department, using painstaking methods of scoring. The percentage of failures, which appears to follow a consistent pattern from year to year, has been quite high, and clearly indicates the value both of this test and of the remedial work provided for those who fail.

MORGAN JOINS DOW

Dr. David H. Morgan, since 1953 President of Texas A. & M. College, College Station, has been appointed Director of College Relations for the Dow Chemical Company at Midland, Michigan. An expert in educational psychology and administration and a member of ASEE since 1952, Dr. Morgan will be responsible for coordinating the whole range of Dow's industry-cooperative activities in the educational field.

GRADUATE PROGRAMS AS PREPARATION FOR ENGINEERING TEACHING

CHARLES R. VAIL

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A paper presented at a joint meeting of the Educational Methods and Graduate Studies Divisions at Ames, Iowa, June 27, 1956. Recommended for publication by the Educational Methods Division.

A two-fold crisis is rapidly approaching in engineering education. On the one hand, even as the need matures for many more engineering teachers to handle the wave of students that is about to engulf us, we find ourselves in a grim but losing competition with industry for the services of our own graduates—and even of our present staff members.

On the other hand, the need is growing for a new type of engineer of sufficient breadth, depth, and versatility to develop the technologies necessary to utilize the new discoveries that modern science is showering upon us. This calls for a uniquely qualified type of engineering teacher. How to meet both of these needs simultaneously is a problem that defies easy solution. The present paper is concerned primarily with but one aspect of this problem: the adequacy of the training of teachers for this dawning new era in engineering education. However, an adequate solution to this problem almost certainly will go a long way toward solving the recruitment problem too.

The necessary characteristics of this new type of engineering teacher are easy to enumerate. They include a solid grounding in the fundamental concepts and practices which constitute traditional engineering. In addition, they include an alertness to new ideas and techniques and a propensity for stimulating their students to apply them imaginatively. In short, if we are to graduate engineers who are creative in the practice of their profession, we must have on our faculties teachers who are creative in their approach to teaching and who can stimulate creativity in their students. In teaching, as in engineering practice, conventionality must begin to yield ground to creativity.

The distinction between conventionality and creativity in engineering practice has been eloquently discussed by C. D. Fulton, who writes:

> Conventional engineering is a network of formulas, data, rules, and static science bound into a firm discipline. It demands rationality, order, repetition, patience, caution, thoroughness, and scholarship. . . . This kind of engineering is a machine-like process and machines are beginning to be employed to do some of it. It is indeed a considerable part of engineering and we have done a good job of teaching it. . . . Creative engineering, on the other hand, operates on emotion, imagination, chance, boldness, rebellion, abandon, flight of fancy, and every other quality which distinguishes the live human being from the inanimate machine.[1]

[1] Fulton, C. D., "On Teaching Creative Engineering," JOURNAL, 45: 794–801, June, 1955.

The time is at hand when we must exploit those qualities of our students that distinguish them from machines. This calls for a fresh approach to the teaching of engineering.

Against this background we can now examine the question as to whether present-day graduate study programs and graduate teaching methods are effective in training teachers qualified for the demands of engineering education today. In approaching this question, it must first be observed that teaching the graduate student and teaching the undergraduate student may involve two quite different approaches.

The undergraduate student has but recently come from an experience of spoon-fed high school education. A period of tapered-off spoon-feeding may be necessary before the average undergraduate is fully capable of assuming the type of responsibility for his own educational destiny that is expected of graduate students.

To bring a student through such a period skillfully and quickly may require special insights into educational psychology. Such insights are unlikely to be attained by an embryo teacher either through the precept or the example of his engineering graduate school teachers.

A similar comment can be made concerning his chances of achieving an understanding of techniques in such important areas of college teaching as evaluation of achievement, personal counseling, and classroom technique. It appears that graduate-level engineering training is notably deficient in providing a perspective of the whole educative process as well as a knowledge of even the most basic techniques needed by a teacher. This is not surprising in a program whose entire focus is the research-based thesis, and which includes no element of training in pedagogy.

When one considers the importance of the teacher in the total educative process, even in college, it is surprising to realize that, of all the major professions, college teaching is the only one for which there is no specific professional preparation. Even the "internship" period of the first several years of teaching usually operates only haphazardly to correct this situation. Paul Klapper has made this point well:

> The novice in every profession is assured of well-intentioned if not helpful supervision and guidance by experienced colleagues of proved competence. This responsibility toward the beginner is generally recognized as a professional obligation, and provision is made for it. But . . . in college teaching we usually find an impressive exception. The young university graduate is entrusted with the teaching of college classes often with no more assistance than is afforded by a catalogue description or a syllabus of the courses he is expected to teach. In a way not yet defined he is expected to become familiar with [the following] essential background information: the preparation of his students, the place of his course in the design of general or special education of the college, prescribed minimum standards of student achievement, and the common or preferred teaching procedures of his colleagues. He is rarely introduced to the students, and, as a rule, no one in authority is overtly curious about what happens in his classroom. . . . We college teachers are a law unto ourselves as far as teaching procedures are concerned, but not all of us have that insight into the total educative process which equips us

to be the sole judges of our teaching effectiveness.[2]

Fortunately, a few institutions are experimenting with a "teaching internship" program to help correct this situation. So far as the influence of the average graduate study program is concerned, however, qualified engineering teachers are not trained, we must conclude, but merely happen.

Our discussion thus far has dealt with the philosophies and techniques that are specific to *teaching*—with the "how" of engineering teaching. On the "what" side of the ledger there is, fortunately, a more favorable entry. The present-day graduate student receives, for the most part, an excellent training in *conventional engineering*, as previously defined. New technologies that are growing out of the fertile soil of modern scientific discovery are being incorporated into our course offerings and research programs with commendably short time delay.

Our pride in this fact must be somewhat tempered by the knowledge that real creativity is a commodity that we are still failing to cultivate as fully as we might. Our undergraduates and our graduate students alike are still being cast unimaginatively into a mold of conventionality because we, ourselves, do not know any other method of production!

Those of our graduate students who enter teaching are likely to do little better in their careers, for the mold that we are using to shape them bears the image of ourselves. Perhaps it is time for us to throw away the mold and to design a new one. We might even give thought to a program of individualized training for selected students as a means of exploiting to the full all the abilities of our potential teachers. Such bold and costly measures are called for if the pressing needs are to be met.

A part of our difficulty in developing good engineering teachers may arise from the fact that we aspire to require the Ph.D. degree of all engineering teachers and that at the same time we place the focus of a Ph.D. program on laboratory research. This emphasis may be appropriate for a future *graduate school* teacher. On the other hand, the man who is not primarily research-minded but who does wish to advance in the profession of *undergraduate* engineering teaching is confronted with a frustrating situation. Such a man, who is to carry the "base load" in an undergraduate program, may find some background in the history of engineering[3] even *more* valuable than experience in research. Equally useful might be the philosophy and psychology of education, the art of counseling, techniques of communicating ideas, and the science of evaluating student achievement. Manifestly we would not wish to establish "normal schools" for training men in teaching at the expense of a good grounding in the engineering they are to teach.

It might not be amiss, however, to consider the possibility of establishing a new route through existing en-

[2] "Problems of College Teaching," *The Preparation of College Teachers*, ed. by T. C. Blegen and R. M. Cooper (Washington: American Council on Education, 1950), pp. 45–46.

[3] See, for example, references listed in: Higgins, T. J., "A Classified Bibliography of Publications on the History and Development of Electrical Engineering and Electrophysics," *The Bulletin of Bibliography* 20: No. 3 to No. 7, Sept.–Dec. 1950 to Jan.–Apr. 1952.

gineering graduate schools to the doctorate for men whose burning ambition is to teach engineering, and to teach it well. Such a route could continue the requirement of the research-based thesis, but would permit in addition a liberal training in the areas basic to teaching.

The specific goals of such a program would be "to develop further the love of learning in its students, to give them some mastery of the techniques by which they may pursue knowledge in their special subjects, and to provide them with some expert knowledge upon which they may build and which they may communicate to their future students as they communicate their enthusiasm for learning."[4] Furthermore, it is highly appropriate that this program be capped, not with some degree which has doubtful prestige, but rather with the degree of Doctor of Philosophy, which means, literally, "teacher of the love of learning."

We are thus brought back to the most important point of all: our urgent need for *creative* teachers of engineering. Such teachers, we now see, would use the best resources of knowledge and technique that modern psychology can provide to communicate to their students their own flaming enthusiasm for the subject that they teach: creative engineering. Our graduate schools of engineering are not at present training such teachers. If we are to meet the challenge of the future, we engineering educators must begin a deliberate "propagation of the species," taking into account the necessity for evolutionary advance. We must train men who are creative teachers of creative engineering; we must so inspire and "fire" them that they are "unable" to do anything but follow a teaching career.

[4] Diekhoff, J. S., *The Domain of the Faculty in our Expanding Colleges* (New York: Harper and Brothers, 1956), p. 52.

SPILHAUS RE-ELECTED TO UNESCO EXECUTIVE BOARD

At the UNESCO Ninth General Conference on December 5, 1956, in New Delhi, India, Dr. Athelstan Spilhaus, Dean of the Institute of Technology, University of Minnesota, was re-elected to the UNESCO Executive Board. A member of ASEE since 1947, Dr. Spilhaus, Vice Chairman of the U. S. National Commission for UNESCO, was returned to the Board on the first ballot as the American representative, with the highest number of votes received by any candidate. The Executive Board is responsible for UNESCO's policy and program in the two-year interval between the General Conferences. Members are elected for four-year terms and are responsible to their governments.

EVALUATION OF THE PART-TIME GRADUATE STUDENT TEACHER

A. H. WAYNICK

Electrical Engineering Department,
The Pennsylvania State University,
University Park

Presented at the Educational Methods Conference,
June 27, 1956, Ames, Iowa.

A program for the development and evaluation of part-time graduate students as engineering teachers is described. The program has been under way for a period of three years and has, it is believed, met with some success.

Selection Process

The first step in finding suitable individuals for participation in an engineering teacher training program is, of course, the selection of the men concerned.

Our own department, involving a large number of undergraduate students, utilizes a scheme which we call our "bright boy" list. In the fall semester, a committee comprised of senior staff and our Department graduate study committee combs the senior class. A group of better students, approximately 15 per cent of the graduating class, is then arrived at on the basis of scholastic record, personal and other qualifications which have resulted in the individual's coming to the favorable attention of several staff members.

Each student on this list is assigned to one or more members of the selection committee, who then interview each student personally. The discussion is directed towards instruction; i.e., the student is informed that, in the opinion of the senior Department staff, he should consider going on into graduate work. Current activities in graduate work within the Department are brought to his attention, and the types of aid available, such as graduate assistantships and fellowships, and how they can be procured, are outlined for his benefit. The interests of the student, such as research, industrial employement, or teaching., are likewise determined during these interviews.

The results of the interviews are assayed by the committee and suitable individuals indicating an interest in proceeding to graduate work are assisted and encouraged as much as possible. Those students interested in and apparently qualified to prepare for engineering teaching are especially helped and guided as outlined in the following.

Advisory Procedure

Most individuals entering into this program as possible future teachers are encouraged to begin as half-time assistants serving as instructors in laboratories for non-electrical engineers—in which the graduates have been found to do an excellent job.

After several semesters of such work the graduate student has reached the stage where his capabilities in graduate work can be assessed, as well as

his capabilities as a beginning instructor. Upon satisfactory completion of the M.S., his work is again reviewed by senior department staff and, if qualified, he is encouraged to proceed towards the doctorate.

Suitable students interested in teaching as a profession are appointed one-half-time instructors in the Department during the time they are engaged on the course work portion of their doctoral studies. During this time they are again expected to devote one-half time to their graduate work and one-half time to Department instructional activities. In this case the individuals concerned are asked to teach both undergraduate electrical engineering courses and laboratories.

Careful selection of courses is made to provide motivation for the student instructors. During the first semester of this "apprenticeship," the student is asked to teach one lecture section and several laboratory sections of the regular E.E. curriculum. In succeeding semesters larger fractions of his time are devoted to lecture sections with less time in laboratories.

Upon completion of the student's own doctoral course work, his qualifications are again re-assessed and, if qualified, he is encouraged to enter into full-time research concerned with his dissertation. This involves no teaching, and he is usually aided by sponsored research in the Department in his field of interest. Upon completion of this work, the student is then encouraged to enter the teaching profession elsewhere, or to gain industrial experience (depending on his own interests and the opportunities available at the time).

Instruction Assistance

The old adage to the effect that "those who can't—teach" was obviously initially suggested by an individual who had never done any teaching himself. Those of us who are engaged in this activity fully realize that it is hard, though stimulating, work. Further, to keep abreast of current advances and to remain at the frontiers of knowledge in one area of specialization, even a narrow one, is an essential requirement in present-day engineering education. The embryo teacher must be made aware of these facts.

Steps Upward

The following things are done to assist the beginning instructor at our institution:

(1) The complexity of the course material which he teaches is increased from semester to semester. This provides the "building blocks" upon which his instructional abilities can be based, and assumes the valid premise that the very best way to learn a subject is to teach it—particularly for fundamentals.

(2) Where several sections of a course are taught, a course outline is provided for the new instructor. This insures continuity between sections and likewise forms the foundation upon which the new teacher can build effectively.

(3) A senior staff member is assigned as course coordinator. This individual insures continuity in the material and the pace at which it is taught. He likewise serves as a preceptor for the new teacher.

(4) One of the major difficulties encountered by beginning teachers is

the determination of the rules under which his department, college, and university operate. These involve not only his teaching duties but also the counseling activities he is expected to provide to his students. This is simplified by a printed "Manual of Procedures for Teachers" which is given to each new instructor. This manual gives concise information with regards to courses, class scheduling and rolls, as well as instructions as to how such procedures are modified and which University publications and reports should be noted to keep abreast of changes in procedure as they occur.

Evaluation Process

As is well known, the evaluation of a beginning university teacher is very difficult because of the many intangibles involved. The bases upon which the qualifications of senior staff are determined, the caliber and acceptance of the courses for which he is responsible, his professional stature and numerous other factors, depend upon a background of several years of successful teaching. These informative backgrounds are not, of course, available for the younger man.

For such younger men, however, the following criteria have been found useful and, in general, valid:

(1) Student reactions. Fortunately, the average engineering student is a serious individual with a rather definite end result in mind. Consequently, he tends to be vocal concerning possible instructional difficulties that may arise, and this can be very helpful for the beginning instructor when suitably channeled.

On occasion it has also been helpful to utilize the guidance afforded by staff-evaluation questionnaires which are proposed and conducted by student organizations. When carried out under suitable conditions these have been found to be of mutual benefit to both students and staff; senior as well as junior.

(2) A second useful scheme is the analysis of individual reactions and results. In the early stages, the qualifications of the individual are readily determined by the course coordinator with whom he works. Since at this stage, the student teacher is directly dealing with a relatively small portion of a large group of students enrolled in a given laboratory, his own attitudes and the results he obtains with his class sections are easily evaluated. At this stage desirable work habits and procedures must be developed with the collaboration of the coordinator.

When the student teacher has progressed to giving his own lectures, the evaluation problem is, of course, more difficult. At this stage these individuals are invited to Department meetings and their participation in discussions and contributions to Department planing provide a guide to their progress. The customary regular staff procedures for evaluation of teaching success are also followed.

Results

The above described program for the encouragement and evaluation of graduate student engineering teacher trainees has been in operation for the last three years. During this time, four students have successfully completed this process with what are believed to be excellent results. Two of these former students are now teachers at other institutions, one is

in government service, and the fourth is working in industry.

At the present time there are seven graduate students in various phases of this program. Six of these are still definitely interested in entering the teaching profession upon completion of their graduate work. It appears to the staff of our department that some program of this general nature is of great importance to the future of engineering education in the face of the current shortage of engineering manpower, and university engineering instructional manpower in particular.

CHEMICAL ENGINEERING PROBLEMS AVAILABLE

The American Institute of Chemical Engineers has recently published nine parts of a series of thirteen booklets, each of which contains problems, ranging in number from 8 to 78, in a specific field of chemical engineering. From three to 15 pages in length, 8½" by 11" in size, the booklets are punched for notebook use; some include lists of recommended readings. The problems, compiled by the Chemical Engineering Education Projects Committee of AIChE, would be of value both to instructors for classroom work and to the students for review purposes.

The topics presently covered are: Humidification, Thermodynamics, Nuclear Engineering, Crystallization, Reaction Kinetics, Absorption-Adsorption-Extraction, Distillation, Heat Transfer, Fluid Flow, Evaporation, Filtration, Economics, and Drying. The remaining four booklets will be published in a few months. They are available at a cost of 25¢ each, or $2.50 for the complete set of thirteen, from the Office of the Secretary, AIChE, 25 West 45th Street, New York 36, New York. Orders for 100 complete sets or 100 copies of any individual booklets carry a 10% discount.

VIEWS AND NEWS CONTRIBUTED BY

The Young Engineering Teachers

T. A. BOYLE, Chairman
Whitmore Lake, Michigan

ROBERT D. LARUE, Editor
Colorado A. & M. College

UNDERSTANDING BEGINS WITH YOU

BRUCE A. HERTIG

Present address: Graduate School of Public Health, University of Pittsburgh
Former Instructor, Sinclair College, Dayton, Ohio

Fourth Annual Young Engineering Teachers Paper Contest, 1955–56, Ohio Section First Place Winner

Perhaps you entered our dual profession as I did, with an adequate engineering background but no experience in education. I was given a course outline, a pat on the back, and a shove into the classroom. Experienced faculty members proffered tips and suggestions; remembering and applying them under fire, I found, was quite a different matter. Fortunately for the students, however, I was assigned to teach laboratory courses, which required a minimum of lecture time and skills.

It soon became apparent that my job required more than *engineering* competence. Therefore, I evolved a system of self-appraisal which I feel has increased my *teaching* competence considerably. At the completion of each term, questions about the semester's work are jotted down on paper. These must be answered fully and objectively; otherwise the procedure becomes invalid. Critical appraisal of the answers will often indicate better ways to present the subject matter. Though some teaching problems remain unsolved, at least they are recognized and can be brought to the attention of experienced persons for discussion.

To give you an idea of the nature of the questions I ask myself, a few representative ones are listed. You will recognize them as being based on accepted teaching principles.

1. Has teaching the course become routine? (Lack of teacher interest can affect class morale adversely.)

2. Were questions and class participation encouraged? (Effective teaching goes beyond mere lecturing.)

3. Was all the material in the course outline covered thoroughly?; if so, in what manner? (To cram half the course into the last week is evidence of poor planning.)

4. Were the standards of performance adjusted to the abilities of the class? (It is useless to plunge into new material if the students lack the background for understanding.)

5. Did the students *learn* the fundamentals? (Formula-plugging and table-thumbing skills are sometimes useful, but are not encouraging to creative thought.)

In some cases, as with questions 3 and 4, the answers may be in direct conflict. In this event, it is up to the administration to decide which should take precedence.

To illustrate the way this introspection can suggest new approaches, consider question 5 as applied to a recent math course. I was not satisfied with the results of this class; too many of the group made a poor showing on the final. On reflection, these factors stood out: (a) consistent errors in fundamental operations; (b) many questions were asked, but only in regard to the solutions of specific problems; and (c) lack of interest, as typified by the plaintive question, "Why do we have to study this?"

I took such queries to indicate: (1) that the answer to a problem was considered an end in itself; and (2) that the students were emphasizing the operational rules without regard to the principles *behind* the rules. Therefore, they were unable to work examination problems which did not fit a memorized pattern.

With the next class, I studiously avoided mention or use of rules in discussions. Instead, I tried the opposite approach, presenting ideas such as: $a + b = c$ becomes $b = c - a$ by subtracting a from both sides. No mention of sign changing, you'll notice, and the elementary concept of maintaining equality is stressed. The rule becomes apparent soon enough, but based this time on *understanding* rather than on *memory*.

To overcome the "answer-is-everything" attitude, a shift of emphasis in home work assignments turned the trick. The number of problems in daily assignment was reduced, but the scope of work was broadened. With each group, the student was required to give one problem the "full treatment"; the rest were to be solved in the usual way. This "full treatment," as I call it, consists of the following steps:

1. The problem is translated into symbols, and general relationships are established among the several variables. It is not unusual to find students who do not see the relationship between

$$2y^2 + 3y - 5 = 4y$$

and the general quadratic form

$$ax^2 + by + c = 0$$

2. Formulas, if used, must be derived. The added practice gained here eliminates much of the mystery surrounding relationships too glibly established in the texts or on the blackboard.

3. The solution is obtained in symbolic form. No steps are to be taken for granted as being obvious.

4. The specific answer is calculated by substitution of numerical values.

A lot of work, you say? Yes, but every step is included. Sometimes relationships are so obvious to us as instructors that we can't conceive of anyone else missing them. Nevertheless, many students seem to lack understanding of basic mathematical concepts. Have you ever seen a term in a fraction cancelled where it isn't a factor? This wouldn't occur so frequently if the above outline were followed as normal procedure.

Dividends

I have noticed some unexpected side benefits since the adoption of the "full treatment" technique: more questions arise about the text discussions; assignments are completed with less nagging; less time is lost in backtracking over the fundamentals. If you feel that carrying a solution to this extreme would not be applicable to your course, at least avoid instilling too much reliance on rules.

Perhaps you can recall a course you have taught in which student understanding reached an apparent low. A little introspection might reveal that the trouble was in your approach. Before I applied the self-appraisal method, I was too ready to condemn the high schools, the students, or the weather for poor class showings. By accepting the challenge that each new group presents, I have found an added incentive for teaching.

BARKER PRESIDENT OF EJC

Joseph W. Barker, Chairman of the Board and President of the Research Corporation, New York City, has been elected President of the Engineers Joint Council for 1957. As President of EJC, he heads a national organization, the membership of which includes 14 national engineering groups, representing more than 200,000 engineers. A member of ASEE since 1926 and a member of the General Council from 1935 to 1938, Dr. Barker replaces Dr. Thomas H. Chilton of E. I. du Pont de Nemours, who was President of EJC during 1956.

BINTZER APPOINTED VICE PRESIDENT

H. Russell Bintzer, previously Director of the Second Century Fund at Washington University, St. Louis, Missouri, has been appointed Vice President of the Carnegie Institute of Technology, Pittsburgh. Upon assuming his duties on March 1, 1957, Mr. Bintzer will coordinate the institution's long-range planning and development programs. A member of ASEE since 1948, he has been Secretary, Vice Chairman, and Chairman of the Cooperative Education Division, as well as National Chairman of this Division's Committee on Relations with the Federal Government.

Teaching Tip—

ON CORIOLIS' ACCELERATION

THEIN WAH

Assistant Professor of Civil Engineering, University of Connecticut, Storrs

It is becoming increasingly the practice to include Coriolis' Law in teaching Dynamics to sophomore students. The text books generally arrive at Coriolis' acceleration by successive differentiation of the components of the displacement vector. This mathematical derivation is the rigorous and therefore proper approach in a text. This method, however, often fails to create in students an appreciation of the physical meaning of Coriolis' acceleration.

More often than not, students accept Coriolis' acceleration on faith, remembering that when motion takes place with reference to a rotating frame, a "supplementary acceleration," in a direction given by certain specified rules, must be added to the other accelerations which are physically more obvious.

At the risk of sounding trivial, therefore, the author proposes to discuss a simple example which he has found helps to clarify the subject.

Because velocity is a vector, acceleration will, in general, involve a component giving the change in the magnitude of the velocity and a component giving the change in the direction of the velocity. Coriolis' acceleration happens to include both of these components.

Consider a particle at rest on a rotating platform (Fig. 1), at a distance r from the axis of rotation. Let M be the point on the platform on which the particle rests. The velocity of the particle is evidently

$$V = V_M = \omega r \qquad (1)$$

where ω is the angular velocity of the platform (i.e. the rotating frame of reference).

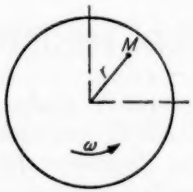

FIGURE 1

The acceleration of the particle (if ω is constant) is

$$a = a_M = \omega^2 r \quad \text{towards the center.} \qquad (2)$$

Suppose next that the particle moves radially outward at a velocity V_r with respect to M. This would be the absolute velocity of the particle if the platform stood still. Since the platform is moving, the absolute velocity of the particle is the vector sum of its velocity with respect to M and the velocity of M,

$$V = V_r + V_M. \qquad (3)$$

If we now assume that the particle moves radially outward with an acceleration of a_r relative to M, then it

would seem logical to write

$$a = a_r + a_M. \tag{4}$$

Equation (4) however ignores two factors which may cause velocity to change: (a) it does not take into account the change in the direction of the velocity vector V_r due to the rotation ω, and (b) it neglects the change in the magnitude of the tangential velocity of the particle due to the change in its distance from the center of rotation. Let us consider each of these in turn.

Because of rotation, the direction in which the particle is moving changes constantly. In a time dt, this change must clearly be $V_r d\theta$, so that the acceleration due to the change in *direction* of the velocity vector is

$$V_r \frac{d\theta}{dt} \equiv V_r\omega.$$

Its direction (Fig. 2) must then be at right angles to that of V_r.

Considering next the change in the position of the particle, its tangential velocity changes in *magnitude* from ωr when it is coincident with M to $\omega(r+dr)$ in a time dt. It follows that the acceleration is $\omega(dr/dt) = V_r\omega$.

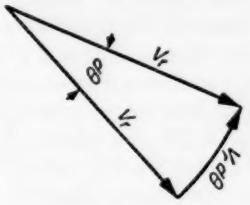

FIGURE 2

Its direction is exactly the same as the component considered previously. Hence a total acceleration of $2V_r\omega$ must be added to the right hand side of equation (4). The direction of Coriolis' acceleration is obvious from the above reasoning.

Of course, since the relative velocity V_r is here assumed to be purely radial, the explanation lacks generality. But in teaching, particular cases often illuminate a general proposition. In that spirit, this note is offered as a "teaching aid," if nothing more.

65th ANNUAL MEETING
CORNELL UNIVERSITY
ITHACA, NEW YORK
JUNE 17-21, 1957

NEW MEMBERS OF ASEE

ARNBERG, BENJAMIN T., Associate Professor of Mechanical Engineering, University of Colorado, Boulder. F. O. Woodsome, B. H. Spurlock.

BARTLETT, FRANCIS GRINDALL, Associate Professor of General Engineering, University of Washington, Seattle, Washington. T. W. Macartney, B. Bonow.

BARTON, CLIFF SMITH, Assistant Professor of Mechanics, Rensselaer Polytechnic Institute, Troy, New York. C. E. Work, W. R. Osgood.

BERNADO, ROBERT FRANCIS, Graduate Assistant in Mechanical Engineering, Worcester Polytechnic Institute, Worcester, Massachusetts. W. P. I. Wellman, F. N. Webster.

BLAKE, JOHN H., Assistant Professor of Chemical Engineering, University of Colorado, Boulder, Colorado. B. E. Lauer, C. L. Eckel.

BOULTON, BERTHOUD C., Executive Assistant to Vice President in Engineering, McDonnell Aircraft Corporation, St. Louis, Missouri. F. Roever, H. Hertenstein.

BROWN, ERNEST LEROY, Acting Assistant Professor of Electrical Engineering, University of Colorado, Boulder, Colorado. W. J. Hanna, S. I. Pearson.

CALHOUN, JOHN D., Associate Professor of Mechanical Engineering, Louisiana Polytechnic Institute, Ruston, Louisiana. S. Baggarly, W. L. Everitt.

CHAPIN, RICHARD EARL, Associate Librarian, Michigan State Library, East Lansing, Michigan. J. D. Ryder, J. W. Hoffman.

CRAWFORD, RICHARD HAZEN, Assistant Professor of Engineering Drawing and Machine Design, University of Colorado, Boulder, Colorado. G. Dobbins, J. M. Allen.

DAILY, HENRY JACKSON, Instructor in Electrical Engineering, University of Kentucky, Lexington, Kentucky. H. A. Romanowitz, N. B. Allison.

DEPREE, JOHN DERYCK, Instructor in Applied Mathematics, University of Colorado, Boulder, Colorado. L. W. Rutland, C. A. Hutchinson.

DILL, ELLIS HAROLD, Assistant Professor of Aeronautical Engineering, University of Washington, Seattle, Washington. J. A. Higbee, V. M. Ganzer.

DORIA, OSVALDO PORRATA, Professor of Electrical Engineering and Head of Department, University of Puerto Rico, Mayaguez, Puerto Rico. T. J. Rung, F. B. Fischer.

DRINKA, MARTIN GEORGE, Instructor in Mechanical Engineering, Marquette University, Milwaukee, Wisconsin. D. E. Schiller, J. P. Bradish.

EMERY, CHARLES LESLIE, Principal in Division of Applied Science, Waterloo College, Waterloo, Ontario, Canada. W. L. Collins, W. L. Everitt.

FOX, ROBERT WILLIAM, Instructor in Mechanical Engineering, University of Colorado, Boulder, Colorado. F. O. Woodsome, B. H. Spurlock, Jr.

GILMORE, ARTHUR WARHAM, Assistant Professor of Aeronautical Engineering, University of Colorado, Boulder, Colorado. F. P. Durham, K. D. Wood.

GRANT, DONALD ANDREW, Instructor in Mechanical Engineering, University of Maine, Orono, Maine. J. R. Lyman, F. J. Sullivan.

GUNKEL, WESLEY WINNFRED, Associate Professor of Agricultural Engineering, Cornell University, Ithaca, New York. L. L. Boyd, G. Levine.

HALLEEN, ROBERT MARVIN, Instructor in Mechanical Engineering, State College of Washington, Pullman, Washington. J. V. Lunsford, H. A. Sorensen.

HOWE, WILLIAM WALTER, Instructor in Engineering, College of Marin, Kentfield, Cal. B. M. Green, C. E. Cherry.

HOWE, WILLIAM WARREN, Head of Chemistry Department, Colorado School of Mines, Golden, Colorado. R. A. Baxter, F. R. Campbell.

HUMPHREY, ARTHUR EARL, Assistant Professor of Chemical Engineering, University of Pennsylvania, Philadelphia, Pennsylvania. M. C. Molstad, G. N. Hixson.

JARDETZKY, WENCESLAS S., Associate Professor of Civil Engineering, Manhattan College, New York, New York. Brother A. Leo, N. V. Feodoroff.

JOHNSON, JAMES KARL, Instructor in Mechanical Engineering, Clemson Agricultural College, Clemson, S. C. J. C. Cook, Jr., J. L. Edwards.

LEPPERT, GEORGE, Associate Professor of Mechanical Engineering, Stanford University, Stanford, California. B. M. Green, A. L. London.

MICKUS, FELIX, Mechanical Engineering Department, General Motors Institute, Flint, Michigan. C. A. Brown, D. G. Roberts.

MONSON, DARREL JAMES, Assistant Professor of Electrical Engineering Science, Brigham Young University, Provo, Utah. B. Brown, L. K. Baxter.

MOSHER, DON R., Assistant Professor of Mechanical Engineering, University of Colorado, Boulder, Colorado. F. O. Woodsome, B. H. Spurlock, Jr.

MCELHANEY, JAMES HARRY, Instructor in Mechanical Engineering, Villanova University, Villanova, Pennsylvania. J. S. Morehouse, G. H. Auth.

NOGGLE, LUKE HAYNIE, JR., Professional Employment in Education, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania. C. H. Ebert, G. E. Moore.

NYSTROM, J. W., Staff Assistant in Research Communication, IBM Research Center, Poughkeepsie, New York. W. Hoyt, E. M. Strong.

O'BANNON, LESTER SEVERANCE, Professor of Mechanical Engineering, A & M College of Texas, College Station, Texas. R. M. Wingren, R. H. Fletcher.

OLDKNOW, J. T., Instructor in Engineering Drawing, University of Colorado, Boulder. G. Dobbins, J. M. Allen.

PATTISON, ROBERT EDWARD, Director of Engineering Training, International Business Machines Corporation, New York, N. Y. W. Hoyt, E. M. Strong.

PLATT, EDWARD K., Assistant Professor of Engineering Drawing, Michigan State University, East Lansing, Mich. E. W. Miller, J. M. Apple.

ROBERTS, JOSEPH LOUIS, Instructor in Mechanical Engineering, New Bedford Institute of Textiles and Technology, New Bedford, Massachusetts. H. C. Tinkham, L. Gonsalves.

RUDOY, WILLIAM, Associate Professor of Mechanical Engineering, University of Pittsburgh, Pittsburgh, Pennsylvania. T. G. Beckwith, N. L. Buck.

SHERIDAN, MARLIN LEE, Associate Professor of Civil Engineering, Bucknell University, Lewisburg, Pennsylvania. D. M. Griffith, R. A. Gardner.

SIMONS, HENRY C., Program Coordinator, Central Training Department, Ford Motor Company, Dearborn, Michigan. A. W. Angrist, D. C. Hunt.

SMETANA, JOHN ALBERT, Assistant Professor of Mechanical Engineering, State College of Washington, Pullman. J. V. Lunsford, H. A. Sorensen.

SMITH, PAUL D., Assistant Professor of Electrical Engineering, Rose Polytechnic Institute, Terre Haute, Indiana. R. D. Strum, H. A. Moench.

STERN, PAUL H., Instructor in General Engineering, University of Washington, Seattle. E. R. Wilcox, B. Bonow.

SZABO, A. J., Associate Professor of Civil Engineering, Southwestern Louisiana Institute, Lafayette, Louisiana. H. M. Morris, E. Dominque.

TATE, BOYCE D., Instructor in Mechanical Engineering, Virginia Military Institute Lexington, Virginia. S. W. Dobyns, J. H. C. Mann.

WADDELL, CLAUDE E., Assistant Professor of Aeronautical Engineering, University of Colorado, Boulder, Colorado. F. P. Durham, K. D. Wood.

WHITEHORNE, ROBERT A., Manager, Engineering Recruitment, International Business Machines Corporation, New York, N. Y. W. Hoyt, E. M. Strong.

WHITWORTH, BILLIE JOE, General Supervisor of the Product Engineering Department, Hughes Tool Company, Houston, Texas. F. H. Berleth, F. Little.

WILLIAMS, JOHN TREW, Assistant Professor of Chemistry, Colorado School of Mines, Golden, Colorado. R. A. Baxter, F. R. Campbell.

50 New Members
335 Previously Added

385 New Members as of December 6, 1956.

ASP-ACSM CONSECUTIVE MEETINGS AND CO-EXHIBIT

The American Society of Photogrammetry and the American Congress on Surveying and Mapping plan their 1957 Consecutive Meetings and Co-Exhibit for March 3–9, at the Shoreham Hotel, Washington, D. C. The technical sessions of the ASP will include papers on many phases of photogrammetric activities, including high altitude photography and the role of photogeology in geological explorations. The six divisions of ACSM will present varied programs on cartographic agencies, control surveys, and other current topics. The Co-Exhibit will display instruments, supplies, and services for photogrammetry, surveying, mapping, and related activities.

JOINT CONFERENCE ON FLUID AND SOLID MECHANICS

The fifth Midwestern Conference on Fluid Mechanics and the third Midwestern Conference on Solid Mechanics will be held concurrently at the University of Michigan, Ann Arbor, on April 1 and 2, 1957. Further information regarding the conference can be obtained by writing to: Jesse Ormondroyd, General Chairman, Joint Mechanics Conference, College of Engineering, University of Michigan.

TEACHING POSITIONS AVAILABLE

ELECTRICAL ENGINEERING teaching positions will be available. Rank and salary commensurate with qualifications and experience. Opportunity for graduate study. Address inquiry to Dr. C. Froehlich, Department of Electrical Engineering, City College of New York, Convent Avenue and 139th Street, New York 31, New York.

CIVIL ENGINEERING ASSISTANT Professors or Instructors needed to teach courses in one or two of the following areas, Surveying, Structures, Hydraulics, or Transportation in metropolitan engineering college. M.S. degree and teaching experience desirable but not required. Positions available in September. Salary open, depending upon education and experience. Please forward complete details of education, professional experience and personal background to Dean Charles E. Schaffner, Polytechnic Institute of Brooklyn, Brooklyn, New York.

ASSOCIATE AND ASSISTANT PROfessors for fields of advanced strength of materials, elasticity, dynamics, and fluid mechanics. Start February or September. Department of Applied Mechanics, University of Kansas, Lawrence, Kansas.

ASSISTANT AND ASSOCIATE PROfessors of Engineering needed. Able young Ph.D.'s interested in teaching and research in equal amounts. Well equipped and active professorial staff in thermodynamics and fluid mechanics is expanding to size comparable with internationally-known group in mechanics of solids. Excellent opportunity for development and advancement. Write to Professors J. Kestin, P. F. Maeder, or R. F. Probstein, or to D. C. Drucker, Chairman of Engineering, Brown University, Providence 12, Rhode Island.

ASSISTANT AND ASSOCIATE PROfessors of engineering interested in teaching and research in equal amounts. Electronics and circuit men preferred to help complement group in electromagnetic theory. Excellent opportunity for development and advancement for qualified young Ph.D.'s. Write to Professor C. M. Angulo, R. D. Kodis, or E. T. Kornhauser or to Chairman of Engineering, Brown University, Providence 12, Rhode Island.

ELECTRICAL ENGINEERING AND Teaching Fellowships in large urban college. Part-time day teaching with tuition-free evening graduate work toward M.S. in Electrical Engineering. Summer employment available. Excellent opportunity for B.S. graduate who wants training for full-time engineering teaching. Salary increases and promotion on attainment of M.S. Also full-time teaching or part-time teaching plus part-time research available in ranks of Assistant Instructor through Assistant Professor. Annual salary increments. Evening teaching, graduate, and undergraduate, available with extra pay. Summer employment available. Apply to F. A. Russell, Acting Chairman, Department of Electrical Engineering, Newark College of Engineering, 365 High Street, Newark 2, New Jersey.

ASSOCIATE PROFESSORS, ASSISTant Professors, or Instructors to teach in the Department of Engineering Drawing, which administers courses in Graphics, Engineering Mechanics, and Engineering Orientation. Rank and salary determined by training and experience. Year-round opportunities for participation in research which replaces part of teaching load during the academic year. Apply to Professor Carson P. Buck, Chairman, Department of Engineering Drawing, Syracuse University, Syracuse 10, New York.

ELECTRICAL AND MECHANICAL Engineering staff openings at Ph.D. and M.S. levels. Salaries commensurate with qualifications. Apply to Dean of Engineering, Duke University, Durham, North Carolina.

MECHANICAL ENGINEERING POSITION available as Assistant or Associate Professor. Advanced degrees required. Unusual opportunity to take a leading part in the development of graduate program. Write to Dean of Engineering, University of Virginia, Charlottesville.

MECHANICAL ENGINEERING, Fluid Dynamics, Electrical Engineering, Physics, and Mathematics teachers needed. Advanced degrees required. Write to President A. B. Bronwell, Worcester Polytechnic Institute, Worcester, Massachusetts.

ELECTRICAL ENGINEERING POSITIONS available in expanding department, having excellent laboratory facilities. Cooperating industries assist in supplying appropriate research facilities. Excellent consulting opportunities, beautiful campus, new buildings, desirable climate, close proximity to the Port of Corpus Christi, Texas, Padre Island, and Mexico. Engineering Drawing Instructors also needed. Write to the Division of Engineering, Texas College of Arts and Industries, Kingsville, Texas.

MECHANICAL ENGINEERING POSITION available for man interested in materials and mechanics or machine design; also position for electrical engineer. Will teach various fundamental courses. Assistant Professor rank, M.S. degree preferred. Apply to Dr. I. O. Addicott, Administrative Dean, Fresno State College, Fresno 26, California.

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GENERAL ENGINEERING INSTRUCTOR and Assistant openings. B.S. engineering degree and good academic record required. Teaching or industrial experience desirable. Graduate study encouraged. Write to R. P. Hoelscher, 116 Transportation, University of Illinois, Urbana.

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ASSISTANT OR ASSOCIATE PROfessor of Electronics needed to teach basic courses in electronics, electronic measurements, industrial electronics, electron tubes, and ultra-high frequency communications and automatic controls. B.S. degree in Physics or Electrical Engineering and industrial experience required; advanced degrees highly desirable. Also Mechanical Engineering Assistant or Associate Professor to teach courses in heat power, laboratory and related lecture courses or production laboratory and related lecture courses, analytic mechanics, descriptive geometry, and engineering drawing; B.S. degree and industrial experience in mechanical engineering or graphics required; advanced degrees highly desirable. Good opportunities in a new department in the process of planning new building and curricula. Good salary scale. Appointments open September, 1957. Write to Dean Stephen L. Walker, Sacramento State College, Sacramento, Calif.

ASEE Reprints Available

The following reprints can be obtained from the ASEE University of Illinois, Urbana, Ill. The prices quoted are for single copies; in lots of 100 or more the price is 12¢ each, except as noted. Please enclose check made out to ASEE with the order.

Final Report on Evaluation of Engineering Education
- Single copies (25¢)
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Improvement of Engineering Teaching (20¢)

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ENGINEERS' COUNCIL FOR PROFESSIONAL DEVELOPMENT

To the Constituent Societies of ECPD and EJC:

Gentlemen:

There is submitted herewith a proposal for a Survey of the Engineering Profession, prepared by a joint committee of ECPD and EJC. This proposal stemmed from the report in 1951 of the ECPD Committee on Adequacy and Standards, culminating in a recommendation from a meeting of 10 deans of engineering colleges who met in June 1954 at Cornell University upon invitation of Dean Hollister. These deans had all been identified with the ASEE report on Evaluation of Engineering Education, and as a result had concluded that a broad survey of the engineering profession was needed. This idea was developed in various informal conferences subsequently and was presented to ECPD early in 1955. As a result the subject was made a principal matter of discussion at the annual meeting of ECPD in Toronto in October 1955. A resolution (Attachment 1) was adopted by Council recommending that such a survey be undertaken, that it be implemented by the Executive Committee, and that endorsement of the constituent societies be sought.

The Executive Committee of ECPD felt that such an important matter affecting the profession as a whole should be explored jointly with EJC. In January 1956, EJC authorized a joint committee, and it was finally consummated and held a meeting in May 1956. At that meeting a subcommittee was appointed to prepare a definitive proposal outlining the need and a tentative program for a survey, to be submitted to the constituent societies. At about the same time the Trustees of the residual funds of American Engineering Council voted to make available these funds on a reimbursable basis to inaugurate the survey.

The ECPD–EJC joint committee recommends to the constituent societies that:

1. They endorse the proposal submitted herewith, recognizing that it is necessarily tentative and illustrative.
2. They endorse the establishment of a Joint ECPD–EJC Committee on a Survey of the Engineering Profession.
3. They authorize funds (perhaps on a membership dues basis) for the initiation of the Survey. Once solid support on the part of the societies is demonstrated, there is indication that other sources will provide substantial underwriting. An immediate subsidy of $50,000 from the other societies is suggested.

The present joint committee regards its task as completed upon the submission of this report. It is firmly of the opinion that a great

need and opportunity confronts the profession which may be discharged by undertaking a comprehensive survey involving, among other factors, the scope outlined in this proposal.

Respectfully submitted,

Joint ECPD–EJC Committee
on
A Survey of the Engineering Profession

J. W. Barker–ASME
Waldo Bowman–ASCE
Crosby Field–ASRE
W. L. McCabe–AIChE
M. P. O'Brien–ASEE
Thorndike Saville–AWWA
Herbert Seward–SNAME
J. S. Smart, Jr.–AIME
K. F. Tupper–EIC
R. G. Warner–NCSBEE
M. D. Hooven–AIEE–*Chairman*

Report of the Joint Committee of the Engineers' Council for Professional Development and the Engineers' Joint Council

ON A SURVEY OF THE ENGINEERING PROFESSION

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The ever-accelerating pace at which expanding scientific knowledge and discovery is rendered useful by the engineer has stimulated a world-wide revolution. By force of momentous advances that are still in progress, the engineering profession has assumed broad responsibilities, among which its traditional concern with individual professional competence is only one. The engineering profession today is the most complex of all. The present shortage in engineering manpower, serious enough by itself, has served further to underscore many other major problems confronting the profes-

sion. It has raised more questions than have been answered.

Critical problems have arisen in every facet of the profession: education, utilization of manpower, organization, and social and economic factors, all of which intimately concern the national welfare. It therefore seems appropriate, necessary and, in fact, urgent that the engineering profession at this time make the first searching and comprehensive self-study in its history.

If it were a matter of numbers alone, the engineering profession and the nation would face a somewhat less formidable problem. But the pattern of the future is already being drawn in the affairs of today. Society and technology have not only utilized the professional competence of the engineer. They look to him to supply managerial and executive ability as well. To cite just one example, answers to the problem of natural resources will almost certainly hinge on the decisions and accomplishments of engineers. The engineer often works without the spur of public concern that, for example, accompanies medical research. More than ever today the engineer must possess the technical and intellectual discernment to anticipate problems and solve them almost before others think of them. Inevitably, engineers make policy in a host of industries and vast government agencies which a decade or two ago looked to the corporation lawyer, the financier, or a political figure for the lead. Just as inevitably, in a period when the battle between freedom and totalitarianism is waged with bread and know-how, national policy must be drafted with the aid of engineers.

The Time Is Now

The decision toward an undertaking so immense as a Survey of the nation's largest profession is not easy and ought not to be made with undue haste. Five years of informal and formal deliberation and introspection lie behind this call for the Survey. It is issued not only because the time is propitious, but also in the belief that delay will do injury to the living and to generations to come. Action born of crisis can be precipitous; but if that action springs from competence, integrity, and authority, it is likely to lead to vast strides forward.

Enlightened Self-Interest as Well

Among the great professions, engineering may take justifiable pride in its reputation. It has been uniquely free of mistrust, scandal, ridicule, and charges of incompetence or inertia. Having earned universal respect, the profession must not complacently assume that this is a permanent grant. If in the future shortcomings should bring deserved criticism upon the profession (to say nothing of abuse and threats to professional freedoms) it will have only itself to blame. Assuming this concern to be, frankly, one motivated by self-interest, it is nevertheless interwoven with the primary obligation of the profession to society.

To measure up to the tasks required of it, the profession must be assured that it is properly training, utilizing, rewarding, and attracting men of the highest competence and potentialities. No responsible person can honestly say that all is well in these areas today. Only a top-to-bottom Survey can determine the nature of the mission, the extent to which it is being fulfilled, and the steps necessary to

maximize our efforts in the most effective manner.

The Personality of the Profession

The profession is composed of individuals. The danger that this will be forgotten grows as the proportion of engineers to other groups increases inexorably. Indeed, neglect of the individual has always been a tendency in a profession distinguished from many others by the fact that most of its members are employees rather than self-employed. Despite emphasis on quantity, society and technology now clearly demand of engineers a high order of intellectual capability, individuality, imagination, and ability to assume responsibility. The Survey must therefore probe not only the day-to-day tasks of the engineer but also his attitudes, hopes, ambitions, disappointments, and fears.

The Spirit of the Survey

Other professions have surveyed themselves thoroughly—under less pressing circumstances than face the engineering profession today. The two most recent studies yielded significant pictures of the American architect and the American lawyer. These are cited merely as a matter of record; only to a minor extent could they serve as models for the Survey of engineering. Engineering's needs seem to call for a type of investigation more akin to the Hoover Commission's study on governmental operations.

The Scope and Uses of the Survey

In each of the great areas, the Survey will:

Seek comprehensive knowledge of the facts of the existing situation.

Formulate answers to many penetrating questions arising from the facts.

Make recommendations for future action.

Provide ways and means of putting the recommendations into actual practice.

If it truly penetrates every aspect and level of engineering, the Survey's constructive conclusions may well be expected to provide guides for the profession for the next quarter-century. Not that engineering should straightjacket itself, for it is by nature dynamic and changing. But the great problems this Survey will attack are of a kind that not only will remain with us for the next generation but may be expected to come into sharper focus and carry even greater significance than now.

Following are the areas with which the Survey must be concerned, together with an indication, not intended to be complete, of questions in each area that cry for investigation and solution:

1. *Professional Services and Responsibilities*

Today the essential of individual technical competence is but a starting point of the engineer's role in society. Past concepts, performance, and evolution of the profession should be analyzed to obtain an up-to-date perspective on present and future problems. Therefore,

What are the strictly professional responsibilities of the engineer?

To what extent do engineers influence the application of their professional efforts?

How effective are the various codes of professional ethics?

What are the gaps in intellectual leadership that could be, should be, filled by engineers?

To what extent should professional education and organization be altered to equip the engineer for new, untraditional services and responsibilities?

2. *The Supply of Brain-power*

To meet the spiralling demands for both capital and consumer goods, the productivity of human effort must be rendered increasingly more effective. At the same time the intricacies and refinements of modern production take a growing percentage of engineering man-hours from inception of an idea to the fabrication and assembly. For example, a 1940 fighter plane took 17,000 man-hours of engineering, a 1955 took 1,410,000, and a 1960 promises to take 2,000,000. Engineering must share with the other professions and intellectual occupations a relatively small reservoir of talented youths. Of the mere 17% of high school graduates intellectually suited to engineering education, engineering colleges are drawing one-fourth of the male portion. A single profession enlisting so great a proportion of this precious human resource assumes grave obligations and responsibilities. Therefore,

From a completely objective and unemotional study, what are the specific shortages, present and projected? Careful statistical studies should deal not alone with the over-all situation but with industries, branches of engineering, and professional levels (consulting, industrial, teaching, and research).

What are the demands of the other professions on the national supply of brain-power? Will these brains have to be rationed? If so, what should be the order of priority?

In general terms, and in case studies, how are engineers utilized?

Depending on the specific shortages disclosed, how can they be alleviated: by regimentation, incentives, better utilization, changes in education, variation of standards, or by other means?

If the growing concentration of numbers in this one profession tends to depress the morale and initiative of its members, how may this be remedied?

3. *The Individual Engineer*

Because he often works in teams and is usually an employee, the individual engineer is too often anonymous. The tributes he has earned are frequently paid to his profession in the mass. Therefore,

What is an engineer? Who is he, and what are his origins and his social, cultural and economic background? For the purposes of outlining an operable framework for the Survey, the Survey Committee must first establish a definition of who shall be termed "an engineer" and therefore be included in the study. To do this, the areas of activity of engineers and those of scientists must be delineated.

Why did he choose engineering? What was the nature of his intellectual preparation, and how did it affect his subsequent career?

What made him choose his particular branch or level of engineering?

How much does he earn, and how much can he expect to earn throughout his career? What are his living standards?

What are his personality traits, and how do they affect his professional performance?

Does the fact that so many engineers are employees adversely affect their professional outlook? Is there a different outlook among those who are self-employed or in policy-making positions?

What are his intimate feelings about his profession, about the organizational pattern in which he functions? How does this pattern encourage or discourage his individual talents, initiative and imagination?

What do his employers and non-professional colleagues, family and friends think of him? How does he rate in his community or in the business world compared with members of other professions?

All other factors being equal, is he more valuable for having remained in one job for many years or having switched often?

What are the effects of pension systems, and other devices to make employment more attractive and reduce turnover, on the freedom and development of the individual engineer?

Does he attempt to advance himself after he leaves college, and by what means?

Does he have non-professional interests, in individual pursuits and in his community?

4. *Sub-Professional Engineering Services*

Like the brain in the central nervous system, the engineer triggers activity by men and women in a greater number of allied occupations and skills: at the same time, he receives information and services from them in order to perform the tasks requiring his particular professional ability and judgment. This is true of other professions, though their allied sub-professional services seem to be more thoroughly and rationally organized. It is ludicrous to imagine a cardiologist or other medical specialist performing the functions of a nurse, an X-ray technician, or a bacteriological aide. Yet many professional engineers are found in comparable situations. Therefore,

What are the specific types of sub-professional services allied to professional engineering? Should more women as well as men be enlisted into them?

To what extent are professional engineers engaged in them?

What are the educational requirements for sub-professional services? What are the existing and needed educational facilities for them?

What kind of people should be attracted to these services?

What recognition can be given them? What opportunities should they have for transfer to professional status?

What mechanical, as well as human, aids are given to the engineer?

To what extent can expanded and better apportioned sub-professional activities alleviate shortages in the profession?

5. *Engineering Education*

The ink is scarcely dry on the last extensive survey of engineering education. More spadework having been done in this area than in any other aspect of the engineering profession, the job of the Survey will be to crystallize the basic problems of engineering education as they relate to other areas of the Survey and to make comprehensive, detailed, and realistic recommendations for solutions. Among

the following questions, the Survey will have considerable information on some, may choose to examine others in still greater detail, and may want to put others to thorough examination by eminent laymen as well as by engineers:

What do we mean by engineering education?

What is the contribution of the educational system to the development of the professional engineer from secondary school through post-graduate study?

Is engineering education too formal, stereotyped, and rigid? Does it foster or inhibit originality and creativity?

What is the actual cost of educating an engineer? How is it paid?

How are engineering schools financed, staffed, and equipped?

What is the composition, ability, and morale of engineering faculties? How may schools retain outstanding faculties in the face of competition from other areas?

What are the causes and implications of the heavy mortality in engineering students?

To what extent should social and humanistic studies be effectively integrated into engineering education?

Should some engineering studies be introduced into educational programs for other professions?

How far should formal graduate work go? Who should pursue it?

To what extent is the advancement and utilization of older engineers (those out of college five years or more) impeded by lack of opportunity or incentive for keeping abreast of new advances in engineering and science?

What procedures can encourage continuing education stimulating to the engineer, not restrictive of his family life and finances, and advantageous to his employer?

6. *Registration and Unionization*

Compared to his invaluable contributions and widespread prestige, the legal status of the engineer and his personal relationship with his profession lag far behind and are relatively ambiguous. The fact that 48 states have registration laws fails to meet the hard truth that while a doctor is a doctor, a lawyer a lawyer, a minister a minister, too often an engineer is all things to all men. Of all the professions, engineering has the most members of labor unions. Therefore,

Should mandatory licensing be expanded? Should engineers be licensed broadly or in particular fields?

Why do engineers register or not register?

Has registration improved engineering ethics and the level of engineering services to the public?

What problems arise from the practice of engineering through the corporate form of business?

What is the nature and extent of unionization?

Why do engineers join unions? How does union membership affect their professional competence and subsequent careers?

What is the organized profession's attitude toward unionization?

Are there advantages and disadvantages in unionization that affect the profession's role in society?

7. *Organization of the Profession*

Many societies, organized along branch lines, flourish within the engi-

neering profession. The societies are organized in two federations. The profession has no true counterpart to the American Medical Association and the American Bar Association. On the other hand, those national organizations are comparatively new institutions in the history of their professions and their function and value, if related to the Survey of engineering, should be studied rationally and objectively. Therefore,

For meaningful organizational purposes, what are the major branches of engineering?

Is the engineering profession cohesive?

What is professional unity and how does it affect maximum professional service?

Are changes in the organization of the engineering profession desirable?

What is the political, social, and economic status of the profession?

What are its relationships to scientific organizations, industrial associations, labor and political organizations, the military, and other professional organizations?

The Role of the Societies

A Survey of the engineering profession will require at least two years. It will cost on the order of $1 million.

The details of organization and procedure of the Survey clearly cannot be spelled out in advance. For one thing, they require long and careful planning. For another, they demand a plan for consultation with all of the constituent societies, a step requiring that the societies first endorse this proposal in general terms.

Generally, however, this Joint Committee suggests the establishment of a Committee on the Survey of the Engineering Profession under the joint auspices of ECPD and EJC.

Following the lead of recent self studies by other professions it seems logical to organize the Survey so that various groups would investigate specific items on which they are best qualified. Such groups need not be composed solely of engineers since engineering embraces a spectrum of activities much broader than the technical competence of the individual engineer. The calibre and distinction of the directing committee should be of a level to arouse enthusiasm and support in areas outside as well as within the profession.

The committee would

Outline a form of organization to conduct the Survey, using the present proposal and supplementary suggestions from the constituent societies as a basis. It will doubtless be desirable to explore the extent to which one or another problem is peculiar to a given segment of the profession, so that special groups in one or more constituent societies may become special agents of the committee.

Appoint a director and small staff to assist in detailing the program and later administering it under the committee's auspices.

Make progress reports to the executive committee of ECPD and the Board of Directors of EJC, so that constituent societies may be continuously informed through their representatives.

Manifestly, the Survey cannot and should not be undertaken without the enthusiastic endorsement and support of the national engineering societies. The unity of the profession on the desirability of the Survey must be un-

mistakable before others are asked to lend their support.

The Reason Within Us

The future pattern of engineering will, to an extent undreamed of by many, influence day-to-day schedules in factories and mines, the size and shape of the national product, the face of the city and countryside, conditions in homes here and abroad, and the respect with which American words are heard at conference tables the world over. This is verified by historical and technological reality and by a sense of great works—wonders, if you will—that lies somewhere in the traditionally unemotional engineer. It is the preservation and extension of that sense that we cite as our final reason for the Survey of the engineering profession.

ATTACHMENT 1

RESOLUTION ON SURVEY OF ENGINEERING PROFESSION

Adopted at the Twenty-Third Annual Meeting of ECPD, on October 14, 1955

WHEREAS: The Profession of Engineering has ever increasing responsibilities in the rapidly expanding technological aspects of our civilization, and

WHEREAS: these public and professional responsibilities are becoming increasingly complex, and

WHEREAS: the engineering personnel being trained is both limited in supply and inadequate in number to discharge the needs under the present organization of the profession, much less those of the future, and

WHEREAS: the situation confronting the profession is charged with important social, economic, and political aspects in the interest of the public welfare, and

WHEREAS: in the light of these serious public and professional problems a study of the profession is called for, now therefore

LET IT BE RESOLVED: That Engineers' Council for Professional Development sponsor a survey of the engineering profession to include the present and prospective needs for engineering services, the improvement in the utilization of engineers and supporting technical personnel, the scope and nature of the education and training required, the problems of registration, unionization and ethics involved, and all other matters pertinent to determine the most effective organization of the profession to meet its public responsibilities and professional opportunities, and

BE IT FURTHER RESOLVED: that Engineers' Council for Professional Development seek the concurrence of its Constituent Societies in undertaking such a survey, and

BE IT FURTHER RESOLVED: that Engineers' Council for Professional Development refers this resolution to its Executive Committee for implementation.

Report of the

NINTH ANNUAL COLLEGE-INDUSTRY CONFERENCE

Midwinter Meeting of the Relations With Industry Division, ASEE

J. M. ENGLISH

Local Chairman, RWI Division
In Charge of Arrangements

Associate Professor of General Engineering
University of California, Los Angeles

Three hundred and ten representatives of industry and colleges of engineering attended the Ninth Annual College-Industry Conference held on the campus of the University of California, Los Angeles, January 30–31, 1957. The Conference was devoted to the topic "Improvement of the Engineer—A Dual Responsibility of the Engineering College and of Industry." The improvement of the engineer was considered as a two-phase problem: as education phase and as professional development. The Conference devoted the closing session to recommendations for action and to consideration of costs.

Some of the important elements suggested for the educational phase were:

a) The basic sciences, mathematics, engineering sciences, and economics should be emphasized and balanced in accordance with the objectives of particular curricula, including design, research, operation, and production.

b) Engineering students should be introduced to the requirements for teamwork involving other engineers, scientists, technicians, and non-technical personnel.

For the professional phase it was suggested that:

a) Industry should encourage continued technical development of the engineer by supporting formal course work, participating in professional and technical societies, and providing special company programs and an adequate professional environment.

b) Individual engineers should recognize the need for the development of the "whole man" as well as the development of the art of engineering through the acquisition of experience, personal judgment, and an intuitive feel for the solution of engineering problems.

c) Industry should provide greater recognition and incentive for professional development in technical pursuits, so that the engineer does not feel that it is necessary to shift into general management to improve his status and salary.

Participants generally agreed that superior engineering faculties must be maintained. However, no easy solution to the problem created by the shift of teachers to industry was developed. Higher salaries were proposed as an obvious remedy, but the complications resulting from differential salary scales on college and university campuses remained unresolved.

More opportunity for engineering faculty members to engage in professional practice on a part-time basis was believed to be essential. This would not only offset the salary differential between universities and industry, but would also serve to keep the faculty in touch with the rapid developments in engineering practice.

SUMMER FACULTY-EMPLOYMENT PROGRAMS—A COMPILATION

CLYDE E. WORK

Associate Professor of Mechanics
Rensselaer Polytechnic Institute, Troy, N. Y.

Because of the benefits derived by both parties from closer relations between engineering faculties and industry, a survey has been made to determine to what extent this relationship can be further developed through summer programs of employment and conferences for faculty members. Companies which had already demonstrated their interest in engineering education by membership in the American Society for Engineering Education were invited to submit information of their activities.

The tabulation presented here has three purposes. It provides professors a summary of some of the opportunities which exist for them in industry for the coming summer with some indication of the kind of activity each company offers. It provides the companies listed with publicity for their programs. It also provides the college relations departments of companies now conducting haphazard or no summer programs with a guide to what can be and is being done by some society-member companies who are leaders in this field.

The compilation is divided into two sections; Part I includes the programs in which special activities are planned to provide professors with as broad a picture of the company's operations as possible. In Part II are listed organizations which offer summer work on a less formal basis.

Certain other related activities not mentioned here are carried out in several companies. These include tours, open houses, faculty visits, and conferences, on a one or two-day basis. It has not been possible to summarize all of this kind of activity in the present paper.

It would be surprising if this compilation is complete. Information received after December 15 could not be included. It is hoped that if this compilation proves to be worth while, it can be revised and perhaps expanded for publication again next year. Comments and supplementary or new information should be addressed to the author.

Key to Symbols Used in Compilation, Columns 5–8

5. Other activities
   - U tours of facilities
   - V social and recreation
   - W luncheons etc. with company personnel

6. Basis for payment
   - S college salary rate
   - Q job assignment and qualifications
   - R honorarium or fixed stipend
   - N no payment (except allowances, Col. 7)

7. Other allowances
   - T travel
   - F food
   - H housing
   - C cost of living

8. Individual assignment
   - J job on company project
   - K study some phase of company's operation
   - L none

PART I. FORMAL PROGRAMS*

Company (Name and address)	*Contact* (Person and position)	1 Backgrounds included	2 Length, weeks	3 Number of participants	4 Number of seminars	5 Other activities	6 Basis for payment	7 Other allowances	8 Individual assignments
Allison Division General Motors Corp. Indianapolis 6, Ind.	R. C. Smith General Supervisor Salaried Personnel Dept.	Tech.	8–12	6–25	4	W	S	T	J
Boeing Airplane Co. Seattle, Wash. Wichita, Kansas Melbourne, Fla.	John C. Sanders Eng'g. Pers. Administrator Boeing Airplane Company Seattle 24, Washington	Tech.	8–12	90–110	15	U,V,W	S	T	J
California Research Corp. 200 Bush Street San Francisco 4, California	D. P. Krotz Asst. to the President	Tech.	8–12	2–5	0	U	Q	T	J
Continental Oil Co. P. O. Box 2197 Houston 1, Texas	Richard R. Crow Asst. Manager Industrial Relations Dept.	Non-Tech.	1–8	5–10	—	—	Q or R	T,F,H	J or K
Convair, Division of General Dynamics Corp. Fort Worth, Texas	H. A. Bodley Administrative Supervisor Engineering Personnel	Tech.	8–12	20–25	2–5	U,V	Q	T	J
Detroit Edison Co. 2000 Second Avenue Detroit 26, Mich.	A. R. Hellarth Asst. to Director of Employment	Tech. Non-Tech.	8–12	5–10	2	U,V,W	Q	T	J
		Tech. Non-Tech.	1	15	11	U,V,W	N	T,F,H	L
Douglas Aircraft Co. Santa Monica, Calif.	C. C. La Vene Employment Manager Engineering Division	Tech.	10+	20–25	—	U	Q	T	J
E. I. Du Pont de Nemours & Co. Wilmington 98, Del.	G. M. Reed Chief Engineer Engineering Dept.	Non-Tech.	3	15–20	—	U	S	T,F,H	J
Esso Research and Engineering P. O. Box 51 Linden, New Jersey		Tech.	12	7–10	—	U	Q	T	J
		Tech.	3 days	20–25	10	U,W	N	T,F,H	L
Ethyl Corporation 1600 W. Eight Mile Road Ferndale 20 Detroit, Mich.	T. J. Carron, Director Employee Training and Development Research Laboratories	Tech.	8–12	2–5	8	U,V	Q	T	J
General Electric Company Schenectady, N. Y. (and others)	W. Scott Hill Janager, Recruiting Eng'g Personnel Department	Tech.	8–12	25–30	20	U,V,W	S	T,C	J
		Tech.	8–12	75–100	—	U,V,W	S	T	J
			1	25–30	15	U,V,W	N	T,F,H	L
General Motors Corporation Detroit 2, Mich.	Kenneth A. Meade Dir. Ed. Relations	Tech.	2	20–30	9	U,V,W	N	T,F,H	K

* See key on preceding page for meaning of symbols under columns 5 to 8.

PART I.—*Continued*

Company (Name and address)	*Contact* (Person and position)	1 Backgrounds included	2 Length, weeks	3 Number of participants	4 Number of seminars	5 Other activities	6 Basis for payment	7 Other allowances	8 Individual assignments
Humble Oil and Refining Company Houston 1, Texas	R. N. Dyer, Head Personnel Division Employee Relations Dept.	Tech. Non-Tech.	8–12	25–35	—	—	Q	T,H	J
International Business Machines Corp. 590 Madison Ave. New York 22, N. Y.	R. A. Whitehorne Manager Engineering Recruitment	Tech.	8–10	30	—	U,W	S	T	J
International Harvester Company 180 N. Mich. Ave. Chicago 1, Ill.	Ernest H. Reed Manager, Education and Personnel Dept.	Tech. & Non-Tech.	3	10–15	11	U,W	R	T,F,H	K
Linde Air Products Company Tonawanda, N. Y. Newark, N. J. Speedway, Indiana	Paul I. Emch Recruiting Coordinator 30 East 52nd Street New York 17, N. Y.	Tech.	10–12	10–15	10	U,V	Q	T	J
Lockheed Aircraft Corporation California Div. Burbank, California	E. W. Des Lauriers Employment Manager	Tech.	8–12	10–25	5	T,W	S	T	J
McDonnell Aircraft Municipal Airport St. Louis 3, Mo.	C. J. O'Toole Asst. Empolyment Manager	Tech.	9+	10–30	—	U,W	Q	T	J
Minneapolis-Honeywell Regulator Company Minneapolis 8, Minn.	A. Lachan Reed Director, Industry-Education Relations	Tech. & Non-Tech.	8–14	20	S-10	U,V,W	S	T	J
Minnesota Mining & Manufacturing Co. Saint Paul 6, Minn.	Wendel W. Burton Employment Manager 900 Fauquier Ave.	Tech.	8–10	S–6	1	U,V,W	S	T	S
North American Aviation Downey, California	John J. Kimbark College Relations Officer Engineering Personnel	Tech.	8–12	10–20	7	U,V,W	Q	T	J
Pratt & Whitney Aircraft East Hartford, Conn.	Roycroft Walsh, Jr. Engineering Department	Tech.	8–12	20–30	5	U,W	S	T	J
Sandia Corporation Sandia Base Albuquerque, New Mexico	W. G. Funk Manager, Employment and Personnel Dept.	Tech.	12	15–25	—	U,V	Q	T	J
Standard Oil Co. Chicago 80, Ill.	R. F. Baldaste Administrative Director Whiting Laboratories Whiting, Indiana	Tech.	8–12	5–6	3	U,V,W	Q	T	J
Stromberg-Carlson Co. Rochester 3, N. Y.	Arthur N. Paul Director of Technical Personnel	Tech.	8+	5–10	—	U,V,W	S	—	J
Sun Oil Company Research & Dev. Dept. Marcus Hook, Pa.	J. Harold Perrine Manager Administriative Div.	Tech.	8–12	2–5	4–6	U,V	Q	—	J

PART I.—*Continued*

Company (Name and address)	*Contact* (Person and position)	1 Backgrounds included	2 Length, weeks	3 Number of participants	4 Number of seminars	5 Other activities	6 Basis for payment	7 Other allowances	8 Individual assignments
U. S. Steel Corp. 525 William Penn Place Pittsburgh 30, Pa.	C. D. Feight, Director Employment and Placement	Tech.	9	10–20	9	U,V,W	S	T	J
Westinghouse Electric Company East Pittsburgh, Pa.	R. Craig Fabian, Supervisor University Relations Education Dept.	Tech.	12–14	20–25	1	U,V,W	R	T,F,H	J

PART II. INFORMAL EMPLOYMENT

Company	*Contact*
Acme Steel Company Chicago 27, Illinois	H. L. Bills, Vice-President and Director of Industrial Relations
Air Reduction Company 150 East 42nd Street, New York 17	F. R. Balcar, Coordinator Research and Engineering
Allis Chalmers Manufacturing Co. Box 512, Milwaukee 1, Wisconsin	Paul A. Bierwagen, Supervisor Graduate Studies, Graduate Training Section
Aluminum Company of America Pittsburgh 19, Pennsylvania	R. L. Gaughler Manager of College Recruitment
Arthur D. Little, Inc. 30 Memorial Drive, Cambridge 42, Mass.	James M. Jager Personnel Director
Caterpillar Tractor Company Peoria, Illinois	N. M. Nelson Employee Relations Manager
Chrysler Institute of Engineering Detroit 31, Michigan	L. R. Baker, Director
The Cleveland Electric Illuminating Co. 75 Public Square, Cleveland 1, Ohio	Charles E. Richards Manager—Production Engineering Dept.
Continental Motors Corp. 8647 Lyndon Street, Detroit 38, Mich.	Peter Altman Vice President
Corning Glass Works Corning, New York	L. W. Larson Director of Training
Eastman Kodak Company 343 State Street, Rochester 4, N. Y.	J. H. Howard, Director Business and Technical Personnel
Electro Metallurgical Co., Niagara Works 137–47th Street, Niagara Falls, N. Y.	Willis W. Lake Administrator–Recruiting
Erie Resistor Corp. Erie 6, Pennsylvania	J. D. Heibel, Vice President Engineering and Research
Food Machinery and Chemical Corp. 161 East 42nd Street, New York 17, N. Y.	J. S. Thomas Technical Personnel Manager
Ford Motor Company 21500 Oakwood Boulevard P. O. Box 2053, Dearborn, Michigan	Francis J. Budde, Section Supervisor Salaried Personnel, Training, and Employee Services Department

PART II.—*Continued*

Contact	*Company*
Hercules Powder Company Research Department, Wilmington 99, Del.	R. S. Voris, Technical Assistant to the Director of Research
International Resistance Company 401 North Broad Street Philadelphia 8, Pa.	Walter J. Gershenfeld Personnel Manager Central Office
Johns-Manville Corporation Twenty-two East Fortieth Street, N. Y. 16	Ledwith J. Brennan Director of Training
Louisiana Power & Light Company 142 Delaronde Street, New Orleans 14, La.	W. H. Senyard Director of Personnel
Monsanto Chemical Company St. Louis 4, Missouri	Robert F. McCoole Technical Personnel Manager
Philco Corporation Philadelphia 34, Pennsylvania	Charles Lupton Manager, College Relations
Phillips Petroleum Company Bartlesville, Oklahoma	D. R. McKeithan Director, Personnel Procurement
Public Service Electric and Gas Co. 80 Park Place, Newark 1, New Jersey	M. D. Hooven Electrical Engineer
The Pure Oil Company 35 East Wacker Drive, Chicago, Ill.	J. J. Stadtherr Training Director
Rohm & Haas Company 1700 Walnut Street, Philadelphia 3, Pa.	John C. Haas Vice President
Shell Development Company Emeryville, California	Mott Souders
Sylvania Electric Products Inc. 1740 Broadway, New York 19, N. Y.	Harris Reinhardt Manager, Organization Development
Vitro Laboratories, Armament Test Activity Eglin Air Force Base, Florida	A. J. Erickson Director
The Youngstown Sheet and Tube Company Youngstown 1, Ohio	John R. Bohue Director of Industrial Relations

ADDENDA TO PART II (Received after Dec. 15, 1956)

Company	*Contact*
American Viscose Corp. Marcus Hook, Pennsylvania	A. Ross Adams Asst. to Vice President
Chemstrand Corporation Decatur, Alabama	A. D. Preston Technical Personnel Manager
Goodyear Tire & Rubber Co. Akron 16, Ohio	David Thomas Manager—College Relations
Hughes Aircraft Company Culver City, California	F. A. Scott, Office of Advanced Studies Research & Development Laboratories
International Paper Company Mobile 9, Alabama	Sameul W. Jenkins Southern Kraft Division
Radio Corporation of America Camden 2, New Jersey	Ward T. Huevelman
Scott Paper Company Chester, Pennsylvania	Richard B. Miller Manager of Corporate Employment
Western Electric Company 195 Broadway, New York 7, N. Y.	M. J. Storey, Superintendent Personnel Administration

ENGINEERING ENROLLMENTS AND DEGREES IN ECPD-ACCREDITED INSTITUTIONS: 1956

SIDNEY J. ARMORE AND HENRY H. ARMSBY

Mr. Armore is Chief, Statistical Services Section, Research and Statistical Services Branch, Office of Education, U. S. Department of Health, Education, and Welfare. Dr. Armsby is chief for Engineering Education, Division of Higher Education. *The authors would like to acknowledge their indebtedness for contributions made during the several stages in the preparation of this article to Leah W. Ramsey, Hazel Poole, and Elizabeth Bentson of the Statistical Services Section staff, who were under the supervision of Mabel C. Rice.*

The term "ECPD-Accredited Institutions" refers to those institutions in which one or more engineering curriculum(s) are accredited by the Engineers Council for Professional Development. Engineering enrollment and degree data for *all* institutions which grant engineering degrees, including those accredited by the ECPD, will be published in the near future by the U. S. Office of Education (Circular No. 494, *Engineering Enrollments and Degrees: 1956*).

Summary

1. Engineering enrollment in ECPD-accredited institutions in the fall of 1956 (242,405 students), was slightly below the all-time high reported for 1947.

2. Engineering enrollment has shown steady and accelerated year-to-year increases since 1951.

3. Male engineering enrollment made up of 12.5% of total male college enrollment, compared with 12.1% the year before.

4. Freshman engineering enrollment has been rising steadily since 1950.

5. Freshmen engineering students accounted for 14.9% of the total first-time male students in 1956, compared with 14.6% the year before.

6. The greatest increase in undergraduate engineering full-time enrollment in 1956 from a year earlier was observed for seniors. This category of enrollment increased 20.7% above the year before.

7. Enrollment of undergraduate part-time and evening students was 26.6% higher than the year before.

8. Enrollment for the master's degree increased a phenomenal 20.8% from a year ago.

9. Enrollment for the doctor's degree rose 7.6% from the year before, reversing the decline observed in 1955.

10. During 1955–56, first-level engineering degrees awarded rose 16.6% from the year before, compared with 14.0% for all first-level degrees awarded.

11. The number of master's degrees in engineering awarded rose 5.3% from the year before, while doctor's degrees awarded in engineering increased 1.8%.

12. The five engineering curricula for which the highest percentages of first-level engineering degrees were awarded for the eight-year period 1948–49 through 1955–56, in the order listed, are: mechanical, electrical, civil, chemical, and industrial.

13. The highest percentage of master's degrees awarded in engineering was in electrical engineering.

14. The highest percentage of post-graduate pre-doctoral degrees awarded in engineering was in naval architecture and marine engineering.

15. During most of the eight years studied, the highest percentage of doctor's degrees awarded in engineering was usually in chemical engineering. In 1955–56, however, electrical engineering doctorates were equal in number to those in chemical engineering. No other fields had as many doctorates.

Introduction

Reports from 100% of the ECPD-Accredited Institutions show that engineering enrollment in the fall of 1956 was slightly below the all-time high of 224,390 reported in 1947. After steady and accelerated year-to-year increases since 1951, total engineering enrollment in the United States and outlying parts in the 151 institutions accredited by the Engineers Council for Professional Development (ECPD) reached a level of 242,405 students in the fall of 1956. This represents a 14.4% increase from the year before as compared with a 13.1% increase in 1955 over a year earlier. The 1956 enrollment level was 64.1% above the recent low point, which occurred in 1951.

While total college enrollment in the United States and outlying parts likewise has shown persistent year-to-year increases since 1951, it has generally been at a slower rate. Total college enrollment in the fall of 1956 rose 10.0% over the year before, and 7.2% in 1955 over a year earlier. Accordingly, the percentage of college enrollment made up of engineering students has risen steadily since 1951, except for a slight drop in 1954. In the fall of 1956, engineering students in institutions accredited by the ECPD accounted for 8.2% of total college enrollment, as compared with 7.9% in 1955.

Since engineering enrollment is composed almost exclusively of men, it is perhaps more appropriate to compare total male students enrolled in engineering curricula with total male college enrollment in the United States and its outlying parts. In the fall of 1956, total male engineering students in ECPD-accredited institutions made up 12.5% of total male college enrollment. This percentage compares with 12.1% in 1955 and 11.6% in 1954.

Undergraduate Enrollment

All levels of undergraduate engineering enrollment in the 151 ECPD-accredited institutions showed increases in the fall of 1956 over the

year before. Freshman engineering enrollment, which amounted to 66,409 in the fall of 1956, has been rising steadily since 1950. The year-to-year increase was 8.6% in 1956 as compared with 10.1% in 1955.

Engineering freshmen made up 9.2% of total first-time college enrollment in all institutions of higher education in the United States and outlying parts in 1956, compared with 9.1% in 1955. When compared with first-time male enrollment, new engineering students accounted for 14.9% in 1956 and 14.6% the year before.

The 48,423 sophomores enrolled in engineering in the fall of 1956 represented an increase of 10.6% over a year ago, while the number of engineering juniors, 39,578, was 14.1% higher. The greatest increase in undergraduate engineering full-time enrollment was observed for seniors. The 33,646 seniors enrolled in ECPD-accredited institutions in the fall of 1956 were 20.7% above the year before.

Part-time and evening undergraduate engineering enrollment in the fall of 1956 totaled 26,021 students for ECPD-accredited institutions. This accounted for 12.0% of total undergraduate engineering enrollment, a higher proportion of this total than has been observed since 1952. Enrollment of undergraduate part-time and evening students in the fall of 1956 was 26.6% higher than the year before.

Graduate Enrollment

Total graduate engineering enrollment in the fall of 1956 for the 124 ECPD-accredited institutions with graduate enrollment increased substantially over a year earlier, and at a higher rate than for undergraduates. Enrollment for the master's degree, 22,242 students, increased a phenomenal 20.8% from a year ago. In 1955, enginering enrollment for the master's degree showed a year-to-year increase of 7.8%, while in 1954 it declined 7.2%.

Enrollment for the doctor's degree in the fall of 1956 for ECPD-accredited institutions amounted to 3,400 students. This represented a rise of 7.6% from the year before, reversing the decline of 3.6 % observed in 1955.

Evening student enrollment is proportionately much higher for graduate than for undergraduate engineering enrollment. In the fall of 1956, the 11,107 evening students enrolled for the master's degree made up about half (49.9%) of total engineering enrollment for the master's degree in ECPD-accredited institutions. This compares with 48.7% for 1955. Evening student enrollment for the master's degree increased 23.9% in the fall of 1956 compared with that for a year earlier.

Evening student enrollment for the doctor's degree in ECPD-accredited institutions totaled 528 in the fall of 1956. This amounted to 15.5% of total engineering enrollment for the doctor's degree in these institutions, compared with 16.1% of the total the year before. Evening student enrollment for the doctor's degree increased 3.9% in the fall of 1956 over a year earlier.

First-Level Degrees

During the 1955–56 academic year, 23,547 first-level engineering degrees were awarded by the 151 ECPD-accredited institutions. This represents an increase of 16.6% from the year before, reflecting higher enrollments of engineering freshmen in 1952. This was the second year that first-level

engineering degrees had shown an increase from the year before. In 1954–55, the number of first-level engineering degrees conferred by ECPD-accredited institutions was 2.5% above the year before.

Total first-level degrees in all fields awarded during 1955–56 in the United States and outlying parts rose an estimated 14.0% from the year before, a lower rate than for first-level engineering degrees. Accordingly, the percentage of total first-level degrees awarded during 1955–56 in the field of engineering was 7.3% a little higher than the comparable percentage of 7.0% the year before.

Advanced Degrees

A total of 4678 master's degrees in engineering were granted by ECPD-accredited institutions in 1955–56, amounting to a 5.3% increase from last year. The number of engineering master's degrees awarded has been increasing steadily since 1953, though at a decreasing rate. The year-to-year increase in master's degrees conferred was 10.8% in 1953–54 and 7.6% in 1954–55.

Total master's degrees to be conferred in all fields during 1955–56, as estimated for the United States and outlying parts, indicated a reduction of 1.3% from a year earlier. In contrast, master's degrees in engineering awarded during 1955–56 by ECPD-accredited institutions made up 8.2% of the total, a rise over the 7.6% noted for the year before. The percentage of total master's degrees accounted for by master's degrees in engineering has been rising steadily since 1952–53, when it was 6.1%.

ECPD-accredited institutions granted a total of 610 doctor's degrees in 1955–56, 1.8% more than the year before. This was the second year of increase in the number of doctor's degrees awarded since 1953–54. In 1954–55, the number of these degrees conferred rose 1.5% from the year earlier.

Total doctor's degrees awarded in all fields in the United States and outlying parts, as estimated for 1955–56, indicates a reduction of 6.4% from a year earlier. The percentage of total doctor's degrees granted in the field of engineering rose to 7.4% in 1955–56 from 6.8% the year before.

Choice of Fields

Analysis of degrees granted by ECPD-accredited institutions during the eight academic years 1948–49 through 1955–56 was made to determine the relative output of engineers in the various curricula. The five engineering curricula for which the largest numbers of degrees were awarded, at each level, were observed and ranked. For purposes of this analysis, the unclassified category was ignored.

There was a consistent pattern of choice indicated by the rank ordering of first-level degrees awarded. Mechanical engineering was first and electrical second, followed by civil, chemical, and industrial, in that order.

Analysis of advanced degrees awarded by ECPD-accredited institutions indicates that the highest percentage of master's degrees was awarded in electrical engineering for each of the eight academic years studied. Mechanical was second for all years but 1955–56, when it moved to third place. Third and fourth place fluctuated between civil and chemical during the three years 1948–49 through 1950–51. During the following five years, however, 1951–52 through 1955–56, chemical engineer-

ing was in fourth place, while civil engineering stayed in third place until the last year, when it replaced mechanical in second place. Fifth position was held by aeronautical during the three years 1948–49 through 1950–51, and by industrial engineering during the last five years.

During most of the years studied, naval architecture and marine engineering had the highest percentage of post-graduate pre-doctoral degrees awarded. The highest percentage of doctor's degrees awarded during these years was almost always in chemical engineering, with electrical engineering second. Mechanical was almost always third for doctor's degrees awarded, metallurgical fourth, and civil engineering fifth.

Notes

The data contained in this report are based on a survey of engineering schools and colleges made in October of 1956 under the joint sponsorship of the U. S. Office of Education and the American Society for Engineering Education. In accordance with an agreement reached by a joint committee of the Office of Education and the ASEE, all institutions listed in the Office of Education Directory of Higher Education [1] which reported the conferral of degrees in engineering during 1955–56 [2] were requested to furnish data. Ten Canadian institutions were also invited to participate in the study. This survey collected enrollment and degree data for all institutions accredited by the ECPD, 66 other United States institutions, and 10 Canadian institutions.

As proposed by the joint ASEE and Office of Education Committee and approved by the ASEE General Council, the statistical tables in this report list individually only those institutions (eligible for active institutional membership in the ASEE) in which at least one curriculum has been accredited by ECPD, but contain summary totals for other engineering schools in the United States and for Canadian institutions.

Requests for the data upon which this report is based were directed to the registrars of the institutions concerned. The Office of Education appreciates the splendid cooperation of these officials, as reflected by a 100% response.

Period covered: Engineering schools were asked to report student enrollment as of October 3, 1956. A few institutions, because of late openings, were unable to report before November. Degree data are for the period July 1, 1955, to June 30, 1956.

Undergraduate students: Institutions were requested to report by class level only those students enrolled definitely as candidates for an engineering degree. "Part-time students" (both day and evening) include students not working toward a degree, as well as degree candidates.

Graduate students: Institutions were requested to report "all students who have been admitted to formal graduate standing and are enrolled in graduate courses, regardless of the number of credit hours carried by the student, and regardless of whether the student's work is administered by the engineering college or the graduate school."

[1] *Education Directory*, 1955–56, *Part III*, "Higher Education" (U. S. Office of Education).

[2] *Earned Degrees Conferred in Higher Educational Institutions*, 1955–56 (to be published in the near future, U. S. Office of Education).

TABLE I

ENGINEERING ENROLLMENTS AND DEGREES IN ECPD-ACCREDITED INSTITUTIONS
1949–1956
(For United States and outlying parts)

Year	Number Enrolled for Their First Engineering Degree (Fall)							No. of First Eng'g Degrees Conferred
	Freshmen	Sophomore	Junior	Senior	5th Year	Part Time and Evening	Total	
1949	36,508	35,648	41,695	50,991	2,326	13,478	180,646	41,793 (1948–49)
1950	29,394	27,242	30,957	37,707	3,150	14,504	142,954	48,160 (1949–50)
1951	34,147	23,408	24,757	27,820	2,946	15,289	128,367	37,904 (1950–51)
1952	45,854	26,636	22,369	23,453	2,563	17,295	138,170	27,155 (1951–52)
1953	52,482	32,953	23,975	21,730	2,396	16,890	150,426	21,642 (1952–53)
1954	55,531	38,345	28,699	22,677	2,323	19,528	167,103	19,707 (1953–54)
1955	61,141	43,775	34,696	27,869	2,323	20,551	190,355	20,200 (1954–55)
1956	66,409	48,423	39,578	33,646	2,686	26,021	216,763	23,547 (1955–56)

Year	Number Enrolled in Work for the Master's Degree[1]			No. of Master's Degrees Conferred[1]	Number Enrolled in Work for the Doctor's Degree			No. o Doctor's Degrees Conferred
	Day Students, Full and Part Time	Evening	Total		Day Students, Full and Part Time	Evening	Total	
1949	10,333	4,746	15,079	4,783 (1948–49)	2,386	155	2,541	417 (1948–49)
1950	8,150	7,425	15,575	4,865 (1949–50)	2,342	453	2,795	492 (1949–50)
1951	6,878	9,574	16,452	5,134 (1950–51)	2,419	456	2,875	586 (1950–51)
1952	7,422	9,996	17,418	4,132 (1951–52)	2,261	669	2,930	586 (1951–52)
1953	8,084	10,321	18,405	3,726 (1952–53)	2,298	703	3,001	592 (1952–53)
1954	8,296	8,776	17,072	4,130 (1953–54)	2,483	796	3,279	590 (1953–54)
1955	9,439	8,968	18,407	4,444 (1954–55)	2,653	508	3,161	599 (1954–55)
1956	11,135	11,107	22,242	4,678 (1955–56)	2,872	528	3,400	610 (1955–56)

	1949	1950	1951	1952	1953	1954	1955	1956
Total college enrollment in U. S.*	2,456,000	2,297,000	2,116,000	2,148,000	2,251,000	2,499,750	[2]2,678,623	2,946,985
Engineering enrollment in U. S.**	198,266	161,324	147,694	158,518	171,832	187,454	211,923	242,405
Per cent engineering to total	8.1%	7.0%	7.0%	7.4%	7.6%	7.5%	[2]7.9%	8.2%

[1] Includes other pre-doctoral.

[2] This figure has been changed by excluding 35 two-year institutions devoted wholly or principally to the training of technicians or other semi-professional personnel. Re-classification of institutions by type necessitated the re-grouping of enrollment data for 1955 on the basis of 1956 classifications, in order to make these two years comparable.

* Includes outlying parts.

** Only in ECPD-accredited institutions, but including outlying parts of U. S.

TABLE II

SUMMARY OF UNDERGRADUATE ENROLLMENTS AND BACHELOR'S OR FIRST PROFESSIONAL DEGREES IN ENGINEERING IN THE UNITED STATES, OUTLYING PARTS, AND CANADA, BY CURRICULUM: 1956

Engineering Curriculum	No. of Schools[1]	No. of First Eng'g Degrees Conferred 1955–56		Number Enrolled for Their First Engineering Degree: Fall 1956									
				Total		1st Yr.	2nd Yr.	3rd Yr.	4th Yr.	5th Yr. of 5-Yr. Curriculum	5th Yr. of Co-operative Program	Part-Time and Special Day Students	Evening Students
		Men	Women	Men	Women								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Schools accredited by ECPD:													
Aeronautical	51	820	1	8,072	62	2,733	2,115	1,587	1,208	58	45	99	289
Agricultural	42	314	—	1,836	2	483	492	457	378	17	1	10	—
Architectural	25	202	3	1,886	36	530	451	369	473	21	17	10	51
Ceramic	15	93	1	826	12	224	242	202	159	8	1	2	—
Chemical	110	2,355	21	17,873	203	5,223	4,645	3,866	3,222	144	185	137	654
Civil	137	3,878	10	25,402	115	6,484	6,233	5,636	5,090	156	227	221	1,470
Electrical	142	5,766	11	53,522	142	13,299	14,046	11,582	9,072	250	432	576	4,407
Engineering Mechanics	1	6	1	33	—	—	15	9	8	—	—	1	—
Engineering Physics	27	252	—	1,752	26	449	501	439	311	33	—	8	37
General Engineering	25	645	2	4,529	31	1,468	1,013	819	792	3	—	74	391
Geological	23	197	—	1,449	3	406	387	315	338	6	—	—	—
Geophysical	4	20	—	238	1	91	71	49	28	—	—	—	—
Industrial[2]	67	1,386	5	7,056	28	1,025	1,532	1,805	2,025	97	62	89	449
Mechanical	134	5,975	10	43,648	121	10,342	10,773	9,674	8,116	351	424	381	3,708
Metallurgical	48	476	1	3,132	13	664	790	725	679	28	23	14	222
Mining	30	190	—	1,220	—	333	317	269	273	11	—	8	9
Naval Arch. & Marine	3	35	—	182	1	26	57	50	47	—	—	3	—
Petroleum	22	501	—	4,563	6	1,407	1,073	1,060	973	19	—	19	18
Sanitary	3	15	—	25	—	2	5	7	11	—	—	—	—
Textile	5	67	—	398	8	103	102	106	91	—	—	4	—
Unclassified	92	14	—	35,563	327	20,502	3,055	161	42	—	8	315	11,807
Other	35	269	5	2,401	20	615	508	391	310	10	49	97	441
Total ECPD	151	23,476	71	215,606	1,157	66,409	48,423	39,578	33,646	1,212	1,474	2,068	23,953
Other U. S. schools	64	2,754	5	34,150	208	11,329	7,346	5,032	3,925	175	364	1,644	4,543
All U. S. schools	215	26,230	76	249,756	1,365	77,738	55,769	44,610	37,571	1,387	1,838	3,712	28,496
Canadian schools	10	1,321	3	9,300	29	3,200	2,230	1,798	1,695	404	—	2	—
Grand Total (U. S. and Canada)	225	27,551	79	259,056	1,394	80,938	57,999	46,408	39,266	1,791	1,838	3,714	28,496

[1] This refers to the number of schools offering given curriculum. Such curriculum may or may not be specifically approved by ECPD.
[2] Includes administrative engineering, management engineering, etc.

TABLE III

Undergraduate Engineering Enrollment as of October 3, 1956, and First Engineering Degrees Conferred in 1955–56, by School

Institution	No. of First Eng'g Degrees Conferred 1955–56		Number Enrolled for Their First Engineering Degree: Fall 1956									
			Total		1st Yr.	2nd Yr.	3rd Yr.	4th Yr.	5th Yr. of 5-Yr. Curriculum	5th Yr. of Cooperative Program	Part-Time and Special Day Students	Evening Students
	Men	Women	Men	Women								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
ECPD accredited schools:												
Alabama												
Ala. Poly.	290	—	2,662	13	1,115	614	534	405	—	—	7	—
Univ. Ala.	124	2	2,218	18	415	362	251	194	—	—	2	1,012
Arizona												
Univ. Ariz.	113	1	1,708	10	661	441	345	259	—	—	12	—
Arkansas												
Univ. Ark.	106	—	1,105	6	338	322	211	235	—	—	5	—
California												
Calif. Tech.	64	—	431	—	185	70	86	90	—	—	—	—
Santa Clara	45	—	365	—	141	77	91	56	—	—	—	—
Stanford	180	1	1,211	6	457	240	260	260	—	—	—	—
U. S. Naval PG Sch.	99	—	278	—	—	—	135	143	—	—	—	—
Univ. Calif.[1]	622	3	2,842	26	416	438	997	998	—	—	19	—
Univ. Sou. Calif.	243	—	1,654	13	154	165	374	315	—	—	182	477
Colorado												
Colo. A. & M.	60	—	694	—	311	191	114	78	—	—	—	—
Colo. Mines	146	—	1,071	3	378	280	234	182	—	—	—	—
Univ. Colo.	281	2	3,355	25	819	636	559	344	52	—	6	964
Univ. Denver	42	—	313	3	108	75	61	39	—	6	13	14
Connecticut												
U. S. Coast Guard	86	—	537	—	244	139	91	63	—	—	—	—
Univ. Conn.	129	—	1,340	—	573	423	187	157	—	—	—	—
Yale Univ.	213	—	566	—	—	188	177	190	11	—	—	—
Delaware												
Univ. Delaware	70	1	521	9	179	133	103	111	—	—	4	—
Florida												
Univ. Florida	259	1	2,205	2	900	530	339	280	—	158	—	—
Georgia												
Ga. Tech.	492	2	3,844	21	1,449	1,054	663	685	—	—	14	—
Idaho												
Univ. Idaho	113	—	833	—	293	227	175	138	—	—	—	—
Illinois												
Bradley	62	—	803	1	301	161	116	73	—	—	13	140
Ill. Inst. Tech.	290	3	5,909	117	391	368	396	276	—	—	13	4,582
Northwestern	98	—	955	8	266	211	142	118	—	123	11	92
Univ. Ill.	664	1	5,731	32	2,140	1,322	1,101	1,144	—	—	56	—

TABLE III—*Continued*

UNDERGRADUATE ENGINEERING ENROLLMENT AS OF OCTOBER 3, 1956, AND FIRST ENGINEERING DEGREES CONFERRED IN 1955–56, BY SCHOOL

Indiana												
Notre Dame	221	—	1,177	—	414	258	280	224	—	—	1	—
Purdue	888	3	5,834	46	1,997	1,418	1,252	1,213	—	—	—	—
Rose Poly	74	—	430	—	149	96	90	87	—	—	8	—
Iowa												
Iowa St. Coll	382	—	3,212	13	1,193	784	718	516	—	—	14	—
St. Univ. Iowa	71	1	765	—	229	224	171	133	—	—	8	—
Kansas												
Kan. St. Coll	130	—	1,740	9	492	486	386	340	1	—	44	—
Kan. Univ	187	—	1,950	17	629	479	475	382	—	—	2	—
Mun. Univ. Wichita	20	—	1,379	3	400	240	137	80	—	—	220	305
Kentucky												
Univ. Ky	144	1	1,751	4	692	504	300	218	—	7	28	6
Univ. Louisville	60	—	625	1	195	145	107	91	88	—	—	—
Louisiana												
La. Poly	73	—	999	1	459	233	182	123	—	—	3	—
La. St. Univ	186	2	2,309	15	1,060	426	456	382	—	—	—	—
S W La. Inst	52	—	757	—	328	211	134	84	—	—	—	—
Tulane	58	—	510	4	211	137	90	76	—	—	—	—
Maine												
Univ. Maine	148	2	1,154	3	407	327	223	190	6	—	4	—
Maryland												
Johns Hopkins	155	—	1,133	—	141	150	118	105	—	—	—	619
Univ. Md	109	—	1,729	14	758	510	201	205	1	—	68	—
Massachusetts												
Harvard	27	—	181	—	—	86	58	34	3	—	—	—
Lowell Tech	28	—	1,260	14	401	176	117	74	—	—	6	500
Mass. Inst. Tech	602	3	2,633	21	627	670	686	671	—	—	—	—
Northeastern	240	1	2,771	24	800	613	550	489	—	343	—	—
Tufts	119	1	612	10	200	164	124	134	—	—	—	—
Univ. Mass	73	—	894	10	309	252	179	164	—	—	—	—
Worcester	124	—	942	—	292	267	204	179	—	—	—	—
Michigan												
Detroit Univ	158	—	1,937	4	508	288	272	225	—	169	46	433
Mich. M. & T	256	—	2,082	7	703	583	439	364	—	—	—	—
Mich. St. Univ	206	—	2,438	6	779	612	614	355	—	—	—	84
Univ. Mich	377	3	3,047	42	794	1,042	642	525	—	—	86	—
Wayne Univ	119	1	1,658	14	532	472	349	229	—	—	90	—
Minnesota												
Univ. Minn	310	—	3,343	17	998	743	661	521	359	78	—	—
Mississippi												
Miss. St. Coll	132	1	1,509	3	525	413	329	244	—	—	—	1
Univ. Miss	34	—	289	2	114	93	48	36	—	—	—	—
Missouri												
Mo. Mines	196	—	2,194	6	701	475	597	427	—	—	—	—
Mo. Univ	170	—	1,427	10	492	402	290	253	—	—	—	—
St. Louis Univ	87	—	698	4	274	204	114	96	—	—	9	5
Wash. Univ. (St. L.)	161	—	1,181	5	402	318	229	187	—	—	—	50

TABLE III—*Continued*

UNDERGRADUATE ENGINEERING ENROLLMENT AS OF OCTOBER 3, 1956, AND FIRST ENGINEERING DEGREES CONFERRED IN 1955–56, BY SCHOOL

Institution	No. of First Eng'g Degrees Conferred 1955–56		Number Enrolled for Their First Engineering Degree: Fall 1956									
			Total		1st Yr.	2nd Yr.	3rd Yr.	4th Yr.	5th Yr. of 5-Yr. Curriculum	5th Yr. of Cooperative Program	Part-Time and Special Day Students	Evening Students
	Men	Women	Men	Women								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Montana												
Mont. Mines	30	—	257	—	88	78	50	41	—	—	—	—
Mont. St. Coll.	102	—	1,066	5	417	360	136	158	—	—	—	—
Nebraska												
Univ. Nebr.	131	1	1,437	6	586	412	279	166	—	—	—	—
Nevada												
Univ. Nevada	42	—	485	4	215	119	98	57	—	—	—	—
New Hampshire												
Dartmouth	19	—	403	—	182	94	60	35	32	—	—	—
Univ. New Hamp.	78	—	665	4	229	193	132	115	—	—	—	—
New Jersey												
Newark	327	1	2,650	26	430	371	350	287	—	—	1	1,237
Princeton	116	—	549	—	169	130	137	113	—	—	—	—
Rutgers	77	1	652	6	292	157	119	88	—	—	2	—
Stevens	159	—	976	—	344	281	177	174	—	—	—	—
New Mexico												
N. Mex. A. & M.	50	—	994	5	257	217	151	132	—	—	242	—
N. Mex. Univ.	77	1	835	14	384	205	143	117	—	—	—	—
New York												
Alfred	47	1	274	5	77	91	59	50	—	—	2	—
Brooklyn Poly.	481	—	3,448	—	425	374	389	326	—	—	—	1,934
City Coll. of N. Y.	446	2	5,558	40	1,731	888	693	775	—	—	—	1,511
Clarkson	126	—	1,038	—	419	258	201	160	—	—	—	—
Columbia	126	1	387	4	—	—	212	179	—	—	—	—
Cooper Union	93	1	723	11	106	105	78	71	—	—	—	374
Cornell	222	1	1,996	13	661	461	343	304	240	—	—	—
Manhattan	169	—	989	—	307	220	267	192	—	—	3	—
N. Y. Univ.	330	—	2,013	6	301	251	275	260	—	—	19	913
Pratt	39	—	468	10	150	130	84	56	—	—	58	—
Rensselaer	438	—	2,601	3	739	640	541	627	—	—	1	56
Rochester	41	—	364	5	100	102	68	39	—	—	—	60
Syracuse	86	—	677	10	236	168	147	136	—	—	—	—
Union Coll.	47	—	548	—	119	112	79	64	—	—	9	165
Webb	10	—	65	—	20	17	13	15	—	—	—	—
North Carolina												
Duke Univ.	85	—	476	1	158	138	95	85	—	—	1	—
N. C. St. Coll.	268	—	3,066	8	1,114	855	618	487	—	—	—	—

TABLE III—*Continued*

UNDERGRADUATE ENGINEERING ENROLLMENT AS OF OCTOBER 3, 1956, AND FIRST ENGINEERING DEGREES CONFERRED IN 1955–56, BY SCHOOL

North Dakota												
N. Dak. Ag. Coll.	104	—	905	—	265	262	210	166	—	—	2	—
N. Dak. Univ.	52	—	692	1	279	169	157	88	—	—	—	—
Ohio												
Akron	33	—	540	6	257	108	47	48	—	38	3	45
Case Inst.	231	—	1,285	—	373	349	274	275	—	—	5	9
Cincinnati	142	—	4,024	4	414	360	270	253	—	180	—	2,551
Fenn Coll.	77	—	1,611	2	260	233	89	60	—	53	—	918
Ohio No. Univ.	19	—	256	2	140	52	37	29	—	—	—	—
Ohio St. Univ.	208	—	3,306	—	1,048	700	576	357	286	18	32	289
Ohio Univ.	87	1	1,008	10	366	283	191	178	—	—	—	—
Toledo	68	—	1,047	6	258	159	81	83	—	—	52	420
Univ. Dayton	52	—	1,016	3	387	136	90	73	—	—	32	301
U. S. Air Force Inst. of Tech.	—	—	86	—	—	—	44	42	—	—	—	—
Youngstown	59	1	1,474	3	354	244	126	92	—	—	—	661
Oklahoma												
Okla. A. & M.	219	—	2,174	21	590	529	549	525	—	—	2	—
Okla. Univ.	269	—	2,791	12	937	606	523	735	—	—	2	—
Tulsa	55	—	622	4	265	173	106	70	—	—	12	—
Oregon												
Oregon St. Coll.	146	—	1,446	6	608	326	289	229	—	—	—	—
Pennsylvania												
Bucknell	61	1	399	5	158	111	74	58	3	—	—	—
Carnegie	279	1	1,833	11	296	285	316	265	—	—	12	670
Drexel	403	2	2,261	10	545	541	372	274	—	208	16	315
Lafayette	99	—	896	—	248	179	110	137	—	—	9	213
Lehigh	302	—	1,563	—	462	422	350	329	—	—	—	—
Pa. St. Univ.	587	2	3,946	18	1,589	943	707	718	7	—	—	—
Pittsburgh	251	2	2,336	6	499	486	416	339	—	—	—	602
Swarthmore	19	—	97	3	24	25	21	29	—	—	1	—
Univ. Pa.	90	—	548	1	192	144	120	93	—	—	—	—
Villanova	118	—	977	—	292	239	185	155	26	—	—	80
Rhode Island												
Brown	39	—	235	1	86	70	49	29	2	—	—	—
R. I. Univ.	68	—	689	5	195	199	178	122	—	—	—	—
South Carolina												
Citadel	81	—	683	—	294	214	101	74	—	—	—	—
Clemson	183	—	1,644	—	833	445	213	153	—	—	—	—
S. C. Univ.	90	—	694	3	116	262	165	154	—	—	—	—
South Dakota												
S. Dak. Mines	103	—	813	9	340	163	190	129	—	—	—	—
S. Dak. St. Coll.	67	1	898	5	373	281	146	103	—	—	—	—
Tennessee												
Univ. Tenn.	174	1	1,931	6	576	462	369	254	—	—	7	269
Vanderbilt	109	2	680	10	226	194	145	114	—	—	11	—

TABLE III—*Continued*

UNDERGRADUATE ENGINEERING ENROLLMENT AS OF OCTOBER 3, 1956, AND FIRST ENGINEERING DEGREES CONFERRED IN 1955–56, BY SCHOOL

Institution	No. of First Eng'g Degrees Conferred 1955–56		Number Enrolled for Their First Engineering Degree: Fall 1956									
			Total		1st Yr.	2nd Yr.	3rd Yr.	4th Yr.	5th Yr. of 5-Yr. Curriculum	5th Yr. of Cooperative Program	Part-Time and Special Day Students	Evening Students
	Men	Women	Men	Women								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Texas												
Tex. A. & M.	392	—	3,072	—	1,282	604	585	576	9	—	16	—
Rice	60	1	662	15	232	188	105	95	57	—	—	—
Southern Meth.	42	—	706	2	199	150	164	95	—	93	7	—
Tex. Coll. A. & I.	37	—	565	—	225	193	90	57	—	—	—	—
Tex. Tech. Coll.	146	—	2,101	6	793	543	435	336	—	—	—	—
Tex. Western	33	—	831	7	307	161	88	72	—	—	—	210
Tex. Univ.	319	1	3,437	16	861	822	998	772	—	—	—	—
Utah												
Utah St. Ag. Coll.	70	—	597	—	217	162	132	86	—	—	—	—
Univ. Utah	136	—	1,185	1	328	309	256	293	—	—	—	—
Vermont												
Norwich	40	—	311	—	134	68	60	49	—	—	—	—
Univ. Vermont	38	—	396	6	160	113	76	53	—	—	—	—
Virginia												
Va. Mil. Inst.	88	—	433	—	174	112	72	75	—	—	—	—
Va. Poly.	217	—	3,024	19	1,072	900	599	459	—	—	13	—
Va. Univ.	70	1	740	—	267	213	143	117	—	—	—	—
Washington												
Univ. Wash.	327	2	2,159	12	827	469	441	416	18	—	—	—
Wash. St. Coll.	115	2	944	5	351	249	177	161	11	—	—	—
West Virginia												
W. Va. Univ.	125	—	1,157	2	317	349	310	167	—	—	14	2
Wisconsin												
Marquette	157	1	1,678	17	369	267	226	235	—	—	12	586
Univ. Wisc.	300	2	4,007	21	1,476	1,013	724	560	—	—	49	206
Wyoming												
Univ. Wyo.	90	—	716	6	280	166	152	113	—	—	11	—
Dist. of Columbia												
Catholic Univ.	63	—	321	—	60	82	58	33	—	—	16	72
Geo. Wash. Univ.	61	1	713	6	144	68	92	33	—	—	382	—
Howard Univ.	17	—	433	6	231	96	60	52	—	—	—	—
Alaska												
Univ. Alaska	10	—	144	2	85	20	9	14	—	—	18	—
Hawaii												
Univ. Hawaii	49	—	507	7	178	157	82	97	—	—	—	—
Total ECPD Schools	23,476	71	215,606	1,157	66,409	48,423	39,578	33,646	1,212	1,474	2,068	23,953

[1] Includes data for the Los Angeles and Berkeley campuses which were reported separately prior to 1955.

TABLE IV

Summary of Graduate Enrollment and Degrees in Engineering in the United States, Outlying Parts, and Canada, by Curriculum: 1956

Engineering Curriculum	No. of Schools[1]	No. of Master's Degrees Conferred in Eng'g 1955–56		Number Enrolled in Work for the Master's Degree: Fall 1956				No. of Post-Grad. Pre-Doctoral Degrees[2] Conferred in Eng'g 1955–56		Number Enrolled in Work for Other Post-Graduate Pre-Doctoral Degrees[2]: Fall 1956				No. of Doctor's Degrees Conferred in Eng'g 1955–56		Number Enrolled in Work for the Doctor's Degree: Fall 1956			
				Total		Day Students, Full-Time and Part-Time	Evening and Special Students			Total		Day Students, Full-Time and Part-Time	Evening and Special Students			Total		Day Students, Full-Time and Part-Time	Evening and Special Students
		Men	Wo.	Men	Wo.			Men	Wo.	Men	Wo.			Men	Wo.	Men	Wo.		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Schools accredited by ECPD:																			
Aeronautical	39	195	3	862	5	504	363	18	—	32	—	32	—	36	—	154	2	113	43
Agricultural	30	63	—	142	—	138	4	—	—	—	—	—	—	9	—	39	—	39	—
Architectural	10	9	—	30	—	30	—	—	—	6	—	—	6	—	—	—	—	—	—
Ceramic	14	28	1	55	1	56	—	1	—	3	—	3	—	14	—	32	—	32	—
Chemical	89	539	3	1,960	17	1,143	834	2	—	31	—	31	—	136	—	621	1	531	91
Civil	95	803	1	2,280	8	1,486	802	16	—	12	—	12	—	59	—	257	2	241	18
Electrical	101	1,125	3	6,840	17	3,035	3,822	28	—	49	1	50	—	136	—	952	3	747	208
Engineering Mechanics	32	63	—	329	4	221	112	—	—	—	—	—	—	16	—	121	—	111	10
Engineering Physics	15	48	—	130	—	68	62	1	—	—	—	—	—	17	—	76	—	73	3
General Engineering	11	54	—	483	2	355	130	—	—	—	—	—	—	2	—	104	—	104	—
Geological	12	8	—	102	1	86	17	—	—	—	—	—	—	1	—	27	—	18	9
Geophysical	3	6	—	20	—	13	7	—	—	—	—	—	—	1	—	4	—	4	—
Industrial[3]	45	339	—	2,028	6	721	1,313	2	—	2	—	2	—	10	—	96	2	57	41
Mechanical	100	736	2	3,661	6	1,885	1,782	21	—	38	—	38	—	61	—	379	4	332	51
Metallurgical	41	132	1	617	1	309	309	6	—	9	—	9	—	72	—	254	2	212	44
Mining	23	24	—	49	—	49	—	5	—	—	—	—	—	3	—	6	—	6	—
Naval Arch. & Marine	3	10	—	27	—	27	—	31	—	71	—	71	—	—	—	—	—	—	—
Petroleum	13	64	—	169	1	138	32	—	—	—	—	—	—	4	—	16	—	16	—
Sanitary	16	56	—	79	—	74	5	2	—	1	—	1	—	8	—	29	—	27	2
Textile	3	8	—	25	2	27	—	—	—	—	—	—	—	—	—	5	—	5	—
Unclassified	28	45	—	1,340	27	123	1,244	—	—	—	—	—	—	—	—	28	—	28	—
Other	38	171	3	659	2	398	263	2	—	—	—	—	—	25	—	182	2	176	8
Total ECPD	124	4,526	17	21,887	100	10,886	11,101	135	—	254	1	249	6	610	—	3,382	18	2,872	528
Other U. S. Schools	6	44	2	287	—	155	132	—	—	—	—	—	—	—	—	2	—	2	—
All U. S. Schools	130	4,570	19	22,174	100	11,041	11,233	135	—	254	1	249	6	610	—	3,384	18	2,874	528
Canadian Schools	10	83	1	216	—	214	2	—	—	—	—	—	—	20	—	75	—	75	—
Grand Total (U. S. and Canada)	140	4,653	20	22,390	100	11,255	11,235	135	—	254	1	249	6	630	—	3,459	18	2,949	528

[1] This refers to the number of schools offering given curriculum. Such curriculum may or may not be specifically approved by ECPD.
[2] Other engineering degrees requiring work beyond the master's degree, but less than the requirements for a doctor's degree.
[3] Includes administrative engineering, management engineering, etc.

TABLE V

Graduate Engineering Enrollment as of October 3, 1956, and Graduate Engineering Degrees Conferred in 1955–56, by School

Institution	No. of Master's Degrees Conferred in Eng'g 1955–56		Number Enrolled in Work for the Master's Degree: Fall 1956				No. of Post-Grad. Pre-Doctoral Degrees[1] Conferred in Eng'g 1955–56		Number Enrolled in Work for Other Post-Graduate Pre-Doctoral Degrees[1]: Fall 1956				No. of Doctor's Degrees Conferred in Eng'g 1955–56		Number Enrolled in Work for the Doctor's Degree: Fall 1956			
			Total		Day Students, Full-Time and Part-Time	Evening and Special Students			Total		Day Students, Full-Time and Part-Time	Eveniag and Special Students			Total		Day Students, Full-Time and Part-Time	Evening and Special Students
	Men	Wo.	Men	Wo.			Men	Wo.	Men	Wo.			Men	Wo.	Men	Wo.		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
ECPD-accredited schools:																		
Alabama																		
Ala. Poly	6	—	24	—	24	—	—	—	—	—	—	—	—	—	—	—	—	—
Univ. Ala	7	—	89	—	19	70	—	—	—	—	—	—	—	—	—	—	—	—
Arizona																		
Univ. Ariz	12	—	231	1	116	116	—	—	—	—	—	—	—	—	25	—	16	9
Arkansas																		
Univ. Ark	9	—	17	1	18	—	—	—	—	—	—	—	—	—	—	—	—	—
California																		
Calif. Tech	82	1	115	—	108	7	13	—	46	—	46	—	22	—	45	—	45	—
Stanford	117	—	518	—	518	—	14	—	31	—	31	—	19	—	81	—	81	—
U. S. Naval PG Sch	65	—	48	—	48	—	—	—	—	—	—	—	—	—	1	—	1	—
Univ. Calif	131	1	571	4	575	—	2	—	—	—	—	—	20	—	205	—	205	—
Univ. So. Calif	155	—	880	5	703	182	1	—	7	—	7	—	—	—	38	—	38	—
Colorado																		
Colo. A. & M	9	—	34	—	34	—	—	—	—	—	—	—	—	—	4	—	4	—
Colo. Mines	13	—	73	—	73	—	—	—	—	—	—	—	4	—	15	—	15	—
Univ. Colo	24	—	240	1	55	186	5	—	6	—	—	6	1	—	7	1	8	—
Univ. Denver	—	—	39	—	9	30	—	—	—	—	—	—	—	—	—	—	—	—
Connecticut																		
Univ. Conn	24	1	96	—	18	78	—	—	—	—	—	—	—	—	—	—	—	—
Yale Univ	35	1	127	—	83	44	—	—	—	—	—	—	16	—	45	—	45	—
Delaware																		
Univ. Delaware	27	—	137	3	33	107	—	—	—	—	—	—	6	—	29	—	17	12
Florida																		
Univ. Florida	23	—	53	1	54	—	1	—	6	—	6	—	1	—	9	—	9	—
Georgia																		
Ga. Tech	66	—	138	—	138	—	—	—	—	—	—	—	5	—	33	1	34	—
Idaho																		
Univ. Idaho	11	—	14	—	14	—	—	—	—	—	—	—	—	—	—	—	—	—

TABLE V—*Continued*

GRADUATE ENGINEERING ENROLLMENT AS OF OCTOBER 3, 1956, AND GRADUATE ENGINEERING DEGREES CONFERRED IN 1955–56, BY SCHOOL

Illinois																		
Bradley	1	—	8	—	—	8	—	—	—	—	—	—	—	—	—	—	—	—
Ill. Inst. Tech.	56	—	467	1	58	410	—	—	—	—	—	—	8	—	87	1	22	66
Northwestern	43	1	194	—	90	104	—	—	—	—	—	—	14	—	52	—	45	7
Univ. Ill.	194	—	333	—	328	5	4	—	—	—	—	—	41	—	178	1	179	—
Indiana																		
Notre Dame	24	—	133	—	35	98	—	—	—	—	—	—	—	—	1	—	—	1
Purdue	173	—	364	9	373	—	—	—	—	—	—	—	43	—	98	—	98	—
Rose Poly	1	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Iowa																		
Iowa St. Coll.	62	—	98	—	98	—	—	—	—	—	—	—	14	—	53	—	53	—
St. Univ. Iowa	21	—	43	—	43	—	—	—	—	—	—	—	4	—	25	—	25	—
Kansas																		
Kan. St. Coll.	23	—	44	—	44	—	—	—	—	—	—	—	1	—	4	—	4	—
Kan. Univ.	19	—	132	—	39	93	1	—	—	—	—	—	1	—	12	—	10	2
Mun. Univ. Wichita	2	—	66	—	—	66	—	—	—	—	—	—	—	—	—	—	—	—
Kentucky																		
Univ. Ky.	17	—	24	—	24	—	—	—	—	—	—	—	—	—	3	—	3	—
Univ. Louisville	13	—	64	—	20	44	—	—	—	—	—	—	—	—	3	—	3	—
Louisiana																		
La. St. Univ.	14	—	124	1	125	—	—	—	8	—	8	—	—	—	—	—	—	—
Tulane	3	—	32	—	14	18	—	—	—	—	—	—	—	—	—	—	—	—
Maine																		
Univ. Maine	14	—	16	—	16	—	—	—	—	—	—	—	—	—	—	—	—	—
Maryland																		
Johns Hopkins	31	—	138	1	75	64	—	—	—	—	—	—	18	—	79	—	79	—
Univ. Md.	25	—	114	1	115	—	—	—	—	—	—	—	4	—	22	—	22	—
Massachusetts																		
Harvard	61	—	78	—	78	—	1	—	—	—	—	—	15	—	98	—	98	—
Lowell Tech.	6	—	16	—	16	—	—	—	—	—	—	—	—	—	—	—	—	—
Mass. Inst. Tech.	418	2	828	6	834	—	61	—	126	1	127	—	82	—	340	4	344	—
Northeastern	52	1	396	1	16	381	—	—	—	—	—	—	—	—	—	—	—	—
Univ. Mass.	—	—	25	—	25	—	—	—	—	—	—	—	—	—	—	—	—	—
Worcester	16	—	25	—	25	—	—	—	—	—	—	—	—	—	—	—	—	—
Michigan																		
Detroit Univ.	—	—	15	—	—	15	—	—	—	—	—	—	—	—	—	—	—	—
Mich. M. & T.	8	—	13	—	13	—	6	—	2	—	2	—	—	—	—	—	—	—
Mich. St. Univ.	25	1	100	—	68	32	1	—	—	—	—	—	6	—	41	—	39	2
Univ. Mich.	233	—	414	4	418	—	—	—	—	—	—	—	28	—	197	—	197	—
Wayne Univ.	32	—	248	4	252	—	—	—	—	—	—	—	—	—	—	—	—	—
Minnesota																		
Univ. Minn.	88	—	236	1	204	33	1	—	—	—	—	—	21	—	104	—	104	—
Mississippi																		
Miss. St. Coll.	8	—	18	—	18	—	—	—	—	—	—	—	—	—	—	—	—	—
Univ. Miss.	—	—	8	—	8	—	—	—	—	—	—	—	—	—	—	—	—	—
Missouri																		
Mo. Mines	6	—	49	—	49	—	6	—	—	—	—	—	1	—	4	—	4	—
Mo. Univ.	16	—	39	—	39	—	—	—	—	—	—	—	—	—	9	—	9	—
St. Louis Univ.	14	—	215	—	5	210	—	—	—	—	—	—	—	—	—	—	—	—
Wash. Univ. (St. L.)	30	—	164	2	166	—	—	—	—	—	—	—	5	—	32	1	33	—

TABLE V—*Continued*

GRADUATE ENGINEERING ENROLLMENT AS OF OCTOBER 3, 1956, AND GRADUATE ENGINEERING DEGREES CONFERRED IN 1955–56, BY SCHOOL

Institution	No. of Master's Degrees Conferred in Eng'g 1955–56		Number Enrolled in Work for the Master's Degree: Fall 1956				No. of Post-Grad. Pre-Doctoral Degrees[1] Conferred in Eng'g 1955–56		Number Enrolled in Work for Other Post-Graduate Pre-Doctoral Degrees[1]: Fall 1956				No. of Doctor's Degrees Conferred in Eng'g 1955–56		Number Enrolled in Work for the Doctor's Degree: Fall 1956			
			Total		Day Students, Full-Time and Part-Time	Evening and Special Students			Total		Day Students, Full-Time and Part-Time	Evening and Special Students			Total		Day Students, Full-Time and Part-Time	Evening and Special Students
	Men	Wo.	Men	Wo.			Men	Wo.	Men	Wo.			Men	Wo.	Men	Wo.		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Montana																		
Mont. Mines	2	—	11	—	11	—	—	—	—	—	—	—	—	—	—	—	—	—
Mont. St. Coll.	7	—	17	—	17	—	—	—	—	—	—	—	1	—	6	—	6	—
Nebraska																		
Univ. Nebr.	6	—	17	—	17	—	—	—	—	—	—	—	—	—	—	—	—	—
Nevada																		
Univ. Nevada	2	—	10	—	10	—	—	—	—	—	—	—	—	—	—	—	—	—
New Hampshire																		
Univ. New Hamp.	2	—	3	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—
New Jersey																		
Newark	147	2	721	3	—	724	—	—	—	—	—	—	—	—	—	—	—	—
Princeton	59	—	73	—	73	—	—	—	—	—	—	—	9	—	37	—	37	—
Rutgers	12	—	70	1	23	48	—	—	—	—	—	—	2	—	24	1	4	21
Stevens	142	1	993	3	—	996	—	—	—	—	—	—	1	—	32	—	—	32
New Mexico																		
N. Mex. A. & M.	7	—	101	—	101	—	—	—	—	—	—	—	—	—	—	—	—	—
N. Mex. Univ.	6	—	282	—	282	—	—	—	—	—	—	—	—	—	5	—	5	—
New York																		
Alfred	4	—	14	—	14	—	—	—	—	—	—	—	—	—	1	—	1	—
Brooklyn Poly.	129	—	1,244	1	73	1,172	—	—	—	—	—	—	13	—	158	2	16	144
City Coll. of N. Y.	47	—	417	2	—	419	—	—	—	—	—	—	—	—	—	—	—	—
Clarkson	3	—	4	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—
Columbia	150	1	577	4	581	—	3	—	—	—	—	—	17	—	146	2	148	—
Cornell	41	1	80	—	80	—	—	—	—	—	—	—	14	—	59	—	59	—
N. Y. Univ.	166	2	637	3	66	574	—	—	—	—	—	—	5	—	119	2	4	117
Pratt	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Rensselaer	49	—	638	—	148	490	—	—	—	—	—	—	9	—	44	—	29	15
Rochester	6	—	47	1	7	41	—	—	—	—	—	—	—	—	6	—	4	2
Syracuse	18	—	579	—	68	511	—	—	—	—	—	—	—	—	48	—	24	24
Union Coll.	3	—	132	16	—	148	—	—	—	—	—	—	—	—	—	—	—	—
Webb	3	—	12	—	12	—	—	—	—	—	—	—	—	—	—	—	—	—

TABLE V—*Continued*

GRADUATE ENGINEERING ENROLLMENT AS OF OCTOBER 3, 1956, AND GRADUATE ENGINEERING DEGREES CONFERRED IN 1955–56, BY SCHOOL

North Carolina																		
N. C. St. Coll.	39	—	97	1	98	—	6	—	16	—	16	—	4	—	16	—	16	—
North Dakota																		
N. Dak. Ag. Coll.	2	—	15	—	15	—	—	—	—	—	—	—	—	—	—	—	—	—
N. Dak. Univ.	6	—	13	—	13	—	—	—	—	—	—	—	—	—	—	—	—	—
Ohio																1		
Case Inst.	51	—	530	3	90	443	—	—	—	—	—	—	9	—	60	—	16	45
Cincinnati	9	—	335	—	13	322	—	—	6	—	6	—	1	—	—	—	—	—
Ohio St. Univ.	78	—	219	—	219	—	1	—	—	—	—	—	12	—	105	—	105	—
Toledo	8	—	44	—	2	42	—	—	—	—	—	—	—	—	—	—	—	—
U. S. Air Force Inst. Tech.	—[1]	—	107	—	107	—	—	—	—	—	—	—	—	—	—	—	—	—
Oklahoma																		
Okla. A. & M.	36	—	110	1	111	—	—	—	—	—	—	—	3	—	10	—	10	—
Okla. Univ.	32	—	80	2	82	—	—	—	—	—	—	—	2	—	—	—	—	—
Tulsa	11	—	43	—	25	18	—	—	—	—	—	—	—	—	—	—	—	—
Oregon																		
Oregon St. Coll.	14	—	30	—	30	—	1	—	—	—	—	—	3	—	8	—	8	—
Pennsylvania																		
Bucknell	2	—	5	—	5	—	—	—	—	—	—	—	—	—	—	1	—	—
Carnegie	39	—	240	4	87	157	1	—	—	—	—	—	16	—	49	—	50	—
Drexel	47	—	400	2	402	—	—	—	—	—	—	—	—	—	—	—	—	—
Lehigh	47	—	123	—	123	—	3	—	—	—	—	—	7	—	30	—	30	—
Pa. St. Univ.	57	—	132	—	132	—	—	—	—	—	—	—	11	—	85	—	85	—
Pittsburgh	49	—	444	—	6	438	—	—	—	—	—	—	—	—	29	—	—	29
Univ. Pa.	51	—	819	2	65	756	—	—	—	—	—	—	5	—	99	—	99	—
Villanova	—	—	17	—	—	17	—	—	—	—	—	—	—	—	—	—	—	—
Rhode Island																		
Brown	1	—	30	2	17	15	—	—	—	—	—	—	—	—	7	—	7	—
R. I. Univ.	8	—	18	—	18	—	—	—	—	—	—	—	—	—	—	—	—	—
South Carolina																		
Clemson	3	—	14	—	14	—	—	—	—	—	—	—	—	—	—	—	—	—
South Dakota																		
S. Dak. Mines	1	—	4	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—
S. Dak. St. Coll.	1	—	18	—	18	—	—	—	—	—	—	—	—	—	—	—	—	—
Tennessee																		
Univ. Tenn.	12	—	227	—	227	—	—	—	—	—	—	—	2	—	11	—	11	—
Vanderbilt	3	—	3	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—
Texas																		
Tex. A. & M.	50	—	82	—	82	—	—	—	—	—	—	—	3	—	14	—	14	—
Rice	2	—	21	—	21	—	—	—	—	—	—	—	—	—	3	—	3	—
Southern Meth.	16	—	848	1	—	849	—	—	—	—	—	—	—	—	—	—	—	—
Tex. Coll. A. & I.	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tex. Tech. Coll.	—	—	7	1	8	—	—	—	—	—	—	—	—	—	—	—	—	—
Tex. Univ.	59	—	167	—	167	—	—	—	—	—	—	—	11	—	48	—	48	—
Utah																		
Utah St. Ag. Coll.	2	—	8	—	8	—	1	—	—	—	—	—	—	—	2	—	2	—
Univ. Utah	8	—	[3]18	—	[3]18	—	—	—	—	—	—	—	13	—	—	—	—	—

TABLE V—*Continued*

GRADUATE ENGINEERING ENROLLMENT AS OF OCTOBER 3, 1956, AND GRADUATE ENGINEERING DEGREES CONFERRED IN 1955–56, BY SCHOOL

Institution	No. of Master's Degrees Conferred in Eng'g 1955–56		Number Enrolled in Work for the Master's Degree: Fall 1956				No. of Post-Grad. Pre-Doctoral Degrees[1] Conferred in Eng'g 1955–56		Number Enrolled in Work for Other Post-Graduate Pre-Doctoral Degrees:[1] Fall 1956				No. of Doctor's Degrees Conferred in Eng'g 1955–56		Number Enrolled in Work for the Doctor's Degree: Fall 1956			
			Total		Day Students, Full-Time and Part-Time	Evening and Special Students			Total		Day Students, Full-Time and Part-Time	Evening and Special Students			Total		Day Students, Full-Time and Part-Time	Evening and Special Students
	Men	Wo.	Men	Wo.			Men	Wo.	Men	Wo.			Men	Wo.	Men	Wo.		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Virginia																		
Va. Poly	29	—	70	—	70	—	—	—	—	—	—	—	3	—	11	—	11	—
Va. Univ	20	—	142	—	29	113	—	—	—	—	—	—	—	—	6	—	6	—
Washington																		
Univ. Wash	44	1	215	—	215	—	—	—	—	—	—	—	2	—	27	—	27	—
Wash. St. Coll	3	—	6	—	6	—	—	—	—	—	—	—	—	—	—	—	—	—
West Virginia																		
W. Va. Univ	8	—	29	—	7	22	—	—	—	—	—	—	3	—	7	—	7	—
Wisconsin																		
Univ. Wisc	74	—	284	—	284	—	1	—	—	—	—	—	28	—	91	—	91	—
Wyoming																		
Univ. Wyo	4	—	13	—	13	—	1	—	—	—	—	—	—	—	—	—	—	—
Dist. of Columbia																		
Catholic Univ	9	—	79	—	69	10	—	—	—	—	—	—	1	—	—	—	—	—
Geo. Wash. Univ	14	—	375	—	—	375	—	—	—	—	—	—	—	—	—	—	—	—
Total ECPD schools	4,526	17	21,887	100	10,886	11,101	135	—	254	1	249	6	610	—	3,382	18	2,872	528

[1] Other engineering degrees requiring work beyond the master's degree, but less than the requirements for a doctor's degree.

[2] The U. S. Air Force Institute of Technology at Wright-Patterson Air Force Base, Ohio, was not included in the *Education Directory*, Part III, 1955–56, and hence was not included in any of the statistical surveys of the Office of Education for 1955–56. It is known, however, that in 1955–56 this institution conferred 16 Master of Science degrees in Electrical Engineering and 6 Master of Science degrees in Nuclear Engineering. These figures may be added to those already reported.

[3] Includes students enrolled for pre-doctoral and doctor's degrees.